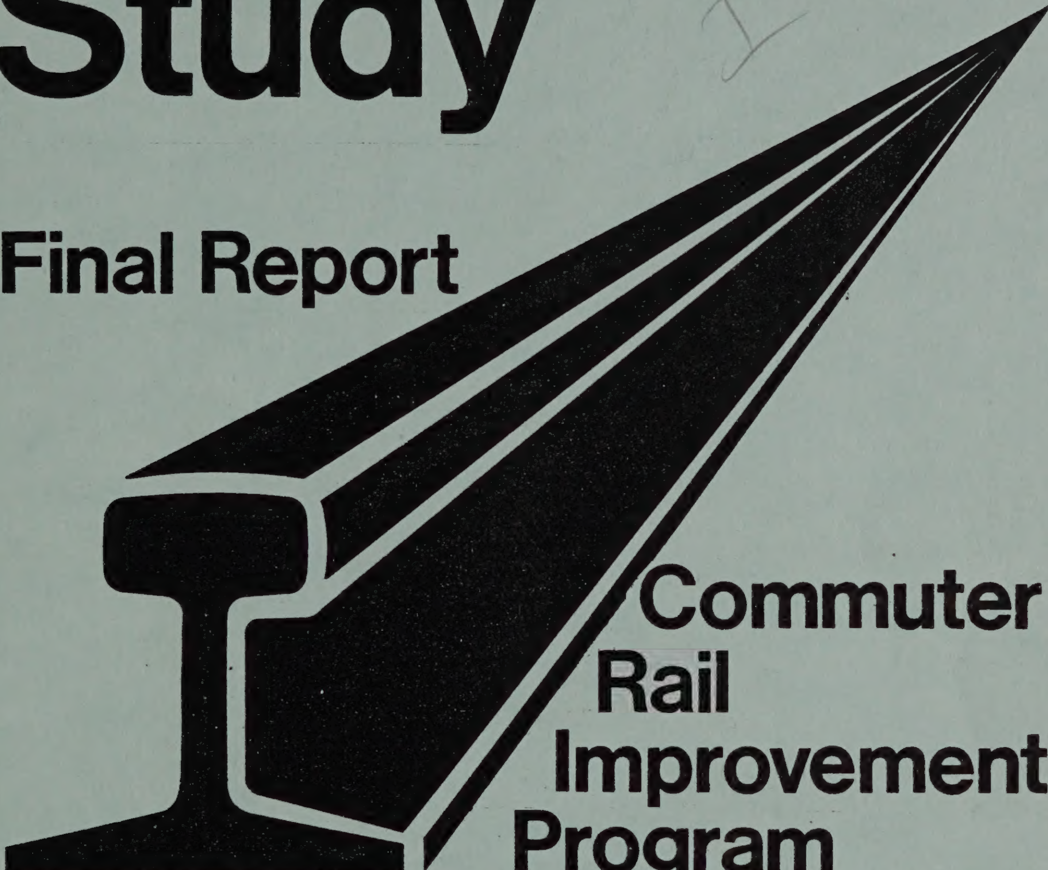
Plan Refinement Study

Final Report



Commuter Rail Improvement Program

This document was prepared by **CENTRAL TRANSPORTATION PLANNING STAFF**, an interagency transportation planning staff created and directed by the Metropolitan Planning Organization, consisting of the member agencies.

Metropolitan Area Planning Council
Executive Office of Transportation and Construction
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Massachusetts Bay Transportation Authority
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PREPARED FOR THE BENEFIT AND USE OF THE MUNICIPALITIES CONSTITUTING THE BOSTON METROPOLITAN AREA PLANNING DISTRICT

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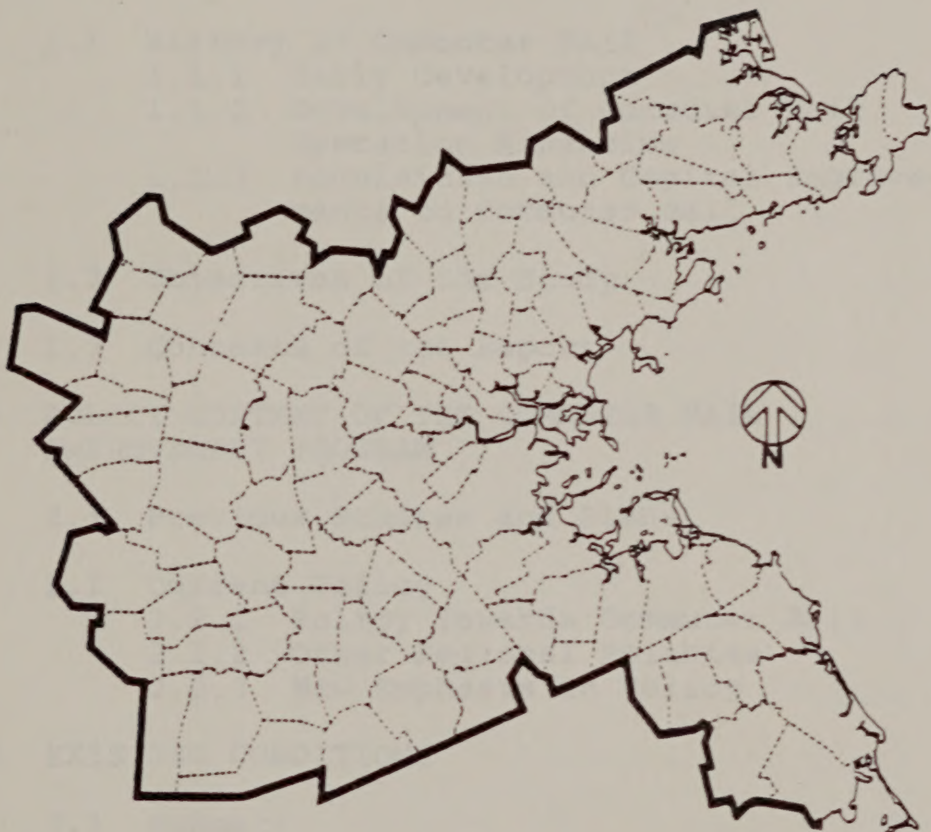

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SUMMARY

The objective of the CRIP Plan Refinement Study has been to provide a thorough analysis of commuter rail and other feasible alternatives for transit service to Boston's suburbs, to determine the best alternative for each commuter rail corridor, and to determine whether and in what form the Commuter Rail Improvement Program should be continued.

CTPS has analyzed different levels of commuter rail service and a commuter bus service with regard to federal, state, and local policy objectives. The impacts of each alternative on operating costs, capital costs, ridership, revenues, traffic flow and regional economic considerations have been estimated. Finally, recommendations regarding capital expenditures and service for each line have been made.

EXISTING CONDITIONS

The commuter rail system in Boston is composed of eight lines and three branches, fanning out over 379 miles of track, 92 stations and 3 terminals in Boston. Service offered includes 230 trains per day into and out of North Station and 98 trains per day into and out of South Station. Almost 30,000 riders per day use the system (15,000 inbound boardings). Ownership of all of the region's commuter rail facilities has been in the MBTA's hands since 1976, although acquisition began in 1973. State subsidies for service began even earlier, in 1965, and in 1977 equaled $26.7 million.

The commuter rail system has lost 21 percent of its riders in the last ten years, during a period in which the equipment used to carry those passengers has continued to deteriorate. Yet in 1977, ridership has started to increase, by 2.5 percent on the Northside and by 5.2 percent on the Southside.

Another positive development occurred in November of 1977 in response to numerous small schedule changes made by the MBTA. These schedule changes were tuned to the needs of commuters along each commuter rail line. Such changes as adding only one additional train or providing

hourly midday service resulted in net ridership increases of 11 to 56 percent in different market segments.

In the market areas served by commuter rail, between 13 and 29 percent of all commuters to downtown take the train to work. This is in contrast to figures from the early 1960s which show a range from 19 to 48 percent. Every market area has suffered a decline, but the most severe declines have been in corridors where the construction of major expressways (the Massachusetts Turnpike and I-93) has provided new competition. In areas where no new highways have been built, commuter rail has fared quite well. On the Shore Line market capture has even increased, from 24 to 27 percent over this time period.

Most users of commuter rail are white collar workers who don't have to take the train. Half come from families with two or more cars. Because of the nature of the service (mostly rush hour service), over 70 percent of all trips are work trips.

Operation of commuter train service into Boston now costs the MBTA almost $35 million a year. For this amount of money, the MBTA carries over 15,000 round trips a day, collecting annual revenues of $8.2 million in 1976 (estimated $9.0 million in 1977).

The system includes 25 locomotives, only 18 of which are operating on a given day; 112 coaches, only 70 of which are typically available for service; and 92 Budd Rail Diesel Cars, with 70 operating on the average. The track has many sections with slow orders. Some of the branches have maximum speeds of only 25 or 30 miles per hour. In addition, numerous bridges are in need of repair, especially on the Eastern Route, which has four very old bridges. Signals on the system are antiquated and require numerous additional operating personnel in signal towers along rights-of-way.

Clearly, many of the commuter rail facilities are not in very good condition. This is primarily due to the lack of investment in the system from the time the private railroads (primarily the Penn Central, its predecessors, and the Boston and Maine) determined that commuter services were losing propositions, and until the State, through the MBTA, purchased the facilities. Major commitments of funds have occurred since that time.

The Commuter Rail Improvement Program (CRIP) Grants Phases I, II, and III, as well as Economic Development Administration (EDA) Grants have purchased the lines for $60.1 million and committed $106.3 million to upgrading the system. Improvements are underway at this time including track work and upgrading of the equipment.

ALTERNATIVES

In the first phase of analysis of commuter rail improvements, four alternatives were analyzed in each commuter rail corridor--three levels of train service and one bus service.

Each of the rail alternatives was designed to meet a specific criterion: Plan A--to serve as a "stop gap" alternative, to ensure continuation of service for 5 to 8 more years, without making an irreversible commitment to commuter rail; Plan B--to make permanent investments in order to provide a reliable, long-life system; Plan C--to significantly upgrade the system and provide fast, frequent, reliable service throughout.

The bus alternative was designed to provide the best possible bus service to the present commuter rail market, serving all of the riders presently served as efficiently as possible. Frequencies of service would vary significantly for the bus alternative; some stations would have increases, some, decreases. The net service change would show an increase in frequency of about four percent from the present commuter rail service. However, many areas served would have significant increases in travel time to downtown, due to the lack of access to a good highway for the express buses to follow.

METHODOLOGY

Ridership on the commuter rail and express bus alternatives was predicted based on data from the November 1976 commuter rail survey, the 1970 census, and various other specialized surveys taken within the last year. Incorporated into the analysis were the effects of changes in travel time, frequency and reliability of service, travel costs, and household income. Comfort (of new rolling stock, for example) was not incorporated, and it is expected that the quarantee of light and heat or air conditioning on every car may increase ridership by as much as 15%.

Operating costs were calculated based on 1977 operations. Cost reductions due to expected improvements in maintenance and equipment utilization due to proposed improvements were factored into the analysis for each alternative. Capital costs were determined based on recent experience or on industry standards.

RESULTS - SYSTEM-WIDE ANALYSIS

Each of the improved commuter rail alternatives would have total operating costs quite close to the costs of the present system, even though each would significantly increase service. This is due to the fact that many of the proposed capital improvements help to decrease costs, especially maintenance and non-productive transportation costs. The various rail alternatives would improve ridership from 25% to 80%. Table S-1 summarizes these results.

Operating costs of the express bus alternative would be less than half of the costs of operating the present rail system. But these savings are not without their shortcomings. The alternative bus system would carry less than two-thirds as many riders as the present rail system, and an even smaller percent of the number of riders than any of the improved rail systems would. In addition, most of the riders of the bus system suffer slower travel times to Boston due to either circuitous routes or congested highways.

Plan A, which is designed to satisfy immediate improvement needs, would cost $53.9 million. Even though the plan was intended to provide an additional lifetime to the present system of only five to eight years, those improvements which need to be done immediately would be longer life investments. Operating costs would decrease by almost $2.3 million, while revenues would increase by $1.4 million. Net cost of service per trip would decrease by almost 20 percent.

Developing a system which would provide stabilized service for the next twenty years or more (Plan B) would attract an additional 4,000 patrons to commuter rail, but would cost almost $150 million. Due to improved equipment and to increased ridership, the deficit would decrease by almost 25 percent.

	Present System	Plan A	Plan B	Plan C	Commuter Bus System
Capital Cost*	--	53,874	149,167	330,375	31,460
Annualized Capital Cost	--	5,883	14,309	31,344	3,904
Operating Cost	34,472	32,206	30,625	43,529	18,136
Annual Revenue	8,670	10,097	11,142	16,357	6,204
Daily Ridership	15,346	17,560	19,330	27,800	10,920
Operating Ratio	0.25	0.31	0.36	0.38	0.34
Operating Deficit	26,312	22,109	19,483	27,172	11,932
Avg. Speed (mph) to end of lines	28.9	29.3	32.3	37.3	27.5
Avg. Frequency (min)	35.0	34.7	34.2	21.2	25.4

*All costs in thousands of dollars

TABLE S-1

SUMMARY OF SYSTEM-WIDE RESULTS

Restoring the commuter rail system to service levels of the late 1950's would cost over $330 million, but at the same time would increase annual revenue 81 percent, to $16.3 million.* This increase in revenue would be more than offset by increased operating costs, resulting in a deficit increase of three percent. Operating cost increases would be moderated somewhat due to elimination of Budd RDC's from service, and due to the reduction in the number of non-operating personnel (at signal towers and one drawbridge).

Elimination of commuter rail service, and the substitution of express bus service in its stead would provide a reduction in costs, but it would also decrease ridership and revenues significantly. To operate the substitute bus service, the MBTA would need to purchase new buses, build one garage to house and maintain these buses and build or modify terminal facilities downtown. The total capital cost for this changeover would be about $31.4 million. Operating costs would be reduced 47 percent, to $18.1 million, while revenues would decrease 28 percent, to $6 million. As mentioned earlier, transit service would be much poorer for some of the present commuter rail users if they had to ride a bus instead. This is particularly true of those travelling from the North Shore (Eastern Route) and from the Southwest Corridor (Shore Line and Franklin Branch). In addition, some users would no longer have direct service to downtown. Instead, their fastest transit option would be to take a local bus to a rapid transit station. This is true for many of the service areas near commuter rail stations which are within Route 128, especially on inner sections of the Reading, Needham, and Franklin Branches and the Shore Line.

RESULTS - LINE-BY-LINE ANALYSIS

After costs, ridership and revenues were determined for each alternative on a system-wide basis, as described above; each commuter rail line was analyzed separately with regard to a series of cost-effectiveness criteria. A summary of this analysis is found in Table S-2.

The results of this analysis show that there is no viable alternative to improved commuter rail service on at least four of the existing routes. On other routes, commuter bus service would be more cost-effective, but in varying

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*Some of this increase in revenue is due to a patronage shift from MBTA express buses on the North Shore to the Eastern Route.

	Present System	Plan A ("GO" Coaches)	Plan B	Plan C	Commuter Bus
EASTERN (incl. Gloucester Branch)					
Inbound Riders	2,250	2,620	3,190	6,860	1,410
NCS/trip	3.33	3.06	2.20	1.70[+]	2.66
REV/(OC+.2ACC)	.266	.314	.355	.415	.312
READING					
Inbound Riders	2,220	1,983	2.740	3,470	1,860
NCS/trip	1.98	1.58	1.09	1.13	0.00[+]
REV/(OC+.2ACC)	.311	.362	.451	.443	.992
NEW HAMPSHIRE (incl. Woburn Branch)					
Inbound Riders	2,140	2,510	2,690	3,820	1,250
NCS/trip	2.54	1.59	1.63	1.56[+]	3.05
REV/(OC+.2ACC)	.311	.419	.413	.424	.273
FITCHBURG					
Inbound Riders	1,600	1,890	1,980	2,340	1,360
NCS/trip	2.55	1.38	1.45	2.07	0.77[+]
REV/OC+.2ACC)	.325	.472	.460	.373	.615
NORTHSIDE SYSTEM					
Inbound Riders	8,510	9,360	10,600	16,490	5,880
NCS/trip	3.29	2.55	2.18	2.00	1.47
REV/(OC+.2ACC)	.253	.305	.339	.362	.429

[+] Alternatives with lowest net cost of service per trip for each line.

Key to Abbreviations: NCS is net cost of service; REV is revenue; OC is operating cost; ACC is annualized (i.e. amortized) capital cost; .2ACC is the state and local share (20%) of ACC.

SUMMARY OF LINE-BY-LINE RESULTS

TABLE S-2 P.1

	Present System	Plan A ("GO" Coaches)	Plan B	Plan C	Commuter Bus
FRAMINGHAM					
Inbound Riders	850	1,120	1,190	1,450	860
NCS/trip	1.43	1.40	1.32	2.85	0.99+
REV/(OC+.2ACC)	.390	.394	.408	.242	.478
NEEDHAM					
Inbound Riders	1,470	1,720	1,850	2,270	1,150
NCS/trip	2.53	3.52	2.41	2.48	0.69+
REV/(OC+.2ACC)	.240	.185	.249	.244	.538
FRANKLIN					
Inbound Riders	1,265	1,550	1,660	2,180	710
NCS/trip	1.49	1.04	1.14+	1.87	5.49
REV/(OC+.2ACC)	.421	.507	.487	.366	.164
SHORE LINE (incl. Stoughton Branch)					
Inbound Riders	3,260	3,810	4,030	5,410	2,320
NCS/trip	2.53	1.50	1.52+	1.89	3.81
REV/(OC+.2ACC)	.281	.397	.395	.343	.206
SOUTHSIDE SYSTEM					
Inbound Riders	6,845	8,200	8,730	11,310	5,040
NCS/trip	2.68	2.24	2.00	2.46	2.86
REV/(OC+.2ACC)	.263	.299	.323	.280	.248

+Alternatives with lowest net cost of service per trip for each line.

Key to abbreviations: NCS is net cost of service; REV is revenue; OC is operating cost; ACC is annualized (i.e. amortized) capital cost; .2ACC is the state and local share (20%) of ACC.

SUMMARY OF LINE-BY-LINE RESULTS

TABLE S-2 P. 2

degrees. This suggests which routes should receive priority for investment. These cost-effectiveness measures not be the sole criterion for discontinuing rail service on any line. Economic impacts (such as jobs, development, and assessed deficit) and freight impacts, as well as other considerations, must be evaluated before such a decision can be made. These are discussed in the following section.

Analyses show that there is no suitable alternative to commuter rail service on four of the existing corridors, the Eastern Route (Ipswich Branch), New Hampshire Division, Franklin Branch, and Shore Line all perform best at some level of rail service. The Eastern Route is discussed below. This study recommends these lines be upgraded to Plan B levels, and that the potential for further improvements be explored. The New Hampshire Division seems to have the greatest potential for attracting new ridership and improved cost-efficiency.

For the other four lines, Reading Branch, Fitchburg Division, Framingham Route, and Needham Branch, as well as for the Gloucester Branch of the Eastern Route, analysis indicates that alternative service would be more cost-effective. On the Gloucester Branch this means a parking facility on the Ipswich Branch, and improved service to that location. Bus service seems to perform better on each of the other lines. Service experiments are recommended to confirm or refute these results.

On the Eastern Route to Ipswich, commuter rail provides the only viable means of offering good public transportation to suburbs beyond Lynn. Therefore, the line should be upgraded to Plan B levels or, if the Blue Line is not extended to Lynn, to Plan C levels. To keep the Gloucester Branch in service, however, requires significant capital investment. Further, a station in Beverly accessible from Route 128 could attract most of the present 600 riders, as well as diverting some travellers from their autos. Such a station facility should be developed immediately, while only essential safety improvements should be made on the branch. Present freight traffic on the branch is light and decreasing, but present shippers seem to have no acceptable alternative mode for shipping (due to present freight tariffs).

The Reading Line has the greatest potential for operation of a cost-effective bus service. Operation of commuter rail is much more expensive than bus, though high capital

investment is not required. Due to I-93 and the Orange Line extension to Oak Grove, ridership continues to decline on the Reading Line. Buses should be made available if ridership does not significantly reverse its trend when new, reliable equipment is operated on the line.

No viable bus alternative is available on the Fitchburg Route until Alewife station on the Red Line is open. At that time, a more cost-effective bus service could be provided into Alewife. In the interim, express train service on the line should be tested. Also, the impact of the Red Line in diverting riders from the Fitchburg Route is difficult to estimate. Hence, service should be retained at least until Alewife Station opens, and then re-evaluated at that time. It is quite possible that the Porter Square Red Line/ commuter rail transfer station will encourage ridership, and merit inclusion of the Fitchburg Route in the long-term rail network.

Bus service in the Framingham Line corridor can be very efficient, especially if provided by private carriers. But, as in the case of the Reading Line, very little capital investment is required to continue service. This study recommends a two-year trial period to determine if improved service can make rail operations more viable on this line.

For the Needham Branch, bus service performs very well and, in addition, bus service will be operated on this line during the reconstruction of the Orange Line in the Southwest Corridor. This bus service should be monitored and re-evaluated after two years of operation to determine if it is the most desirable long-range alternative.

REGION-WIDE IMPACTS OF A COMPOSITE SYSTEM

After analyzing alternative commuter service in each corridor, a "composite system" was analyzed in order to examine the impacts of the most radical possible change in service consistent with the findings presented above--in other words, the service that would result if, after the trial period, all of the lines being tested were to receive bus instead of rail service, and all the other lines were to receive stabilized or major upgraded rail service. This composite network would have bus service operation on the Reading and Fitchburg Lines to the north, and on the Framingham and Needham Lines on the Southside. Parking facilities near Rte.

128 on the Ipswich Branch would provide alternative service for the Gloucester Branch. This configuration was tested for environmental and economic impact analysis purposes, and does not represent a determination of policy on system configuration. The impacts that would be incurred if bus service were implemented as described above include impacts on access highways, on local streets in the vicinity of downtown terminals, and on the regional economy.

The primary access highways that would be used are the Massachusetts Turnpike, Storrow Drive, I-93 and the Mystic River Bridge. Each of these has its own operational problems, but for the most part substitute buses would not create a major strain on the highway system. The additional auto traffic resulting from present commuter rail users who would decide not to take the substitute express buses could aggravate some existing trouble spots, including the merge point of I-93 and the Mystic River Bridge. The net impact of improved rail in some corridors and commuter bus in others would be little if any increase in traffic. Some routes might suffer increases while others had decreases in traffic. Downtown streets in the vicinity of potential bus terminals are relatively free of congestion at this time, and it is not expected that substitute bus service would change this. However, some passengers would have to alight in locations other than the existing commuter rail terminals. The impact on each passenger would depend on his or her final destination.

The full economic impacts of the elimination of commuter rail service are hard to determine. There are three types of impacts which should be considered. The first is the impact on land development, the second is the impact on freight movement, and the third is the impact on the MBTA deficit assessments.

Numerous studies have shown that accessibility is important to economic development. Transit is one means of providing accessibility. Yet, there are numerous other factors which can have an even larger influence. Even so, the presence of good transit access to the downtown area of Boston from the suburbs, such as provided by commuter rail, is an important factor in maintaining the economic health of the regional center. To a lesser extent, suburban cities and towns regard the commuter rail stations as important to the economic health of their traditional local centers. Further, a number of apartment complexes have located on commuter rail lines to benefit from the accessibility afforded by those lines.

Freight service is operated over many of the rights-of-way that also have commuter rail service. In 1976, over 200 shippers received freight in this way (the number is decreasing slightly every year). If commuter rail service were abandonded, the B&M would be unable to continue providing freight service on many of these lines, since the MBTA is paying for maintenance of the rights-of-way (the B&M pays a "freight credit" for this use, but it does not approach the total cost of maintaining the line).

On several of those lines where continuance of commuter rail service is least cost-effective, the amount of freight carried is small. This is true for the Needham and Gloucester Branches. On the Reading Line the majority of freight movement is directed to the Boston-Somerville area and only a small amount to the outer segments of the route. During the period of testing service on these lines there should be a study, in greater depth than has been accomplished under the scope of this report, of the significance of the commuter rail subsidy to continued freight operations on these lightly used segments on the significance of rail service to employment in the industries served, and on the possible need for and magnitude of rail freight subsidies. The Fitchburg route is different. It is a main freight route and freight service would probably continue no matter what happens with the commuter service. Future commuter rail service would have even less significance for the Framingham Route since it is the primary freight route in Massachusetts.

In 1977 dollars, the composite system gross costs are 19 percent lower than 1977 costs for the existing commuter rail system. In 1985 the estimated assessed deficit of the composite system would be $13.5 million, an increase of 31 percent over 1977 levels. The majority of the 79 cities and towns being assessed for this deficit would experience a 20 to 40 percent increase over 1977 charges. These figures include an annual inflation rate of about seven percent applied to operating costs.

When comparing the composite system with a system that continues rail in all corridors, individual communities show varying results. All communities but three would have lower assessments with the composite system. For most of the inner 14 communities the savings on commuter rail related assessments would be nearly 50% (due to the manner in which "express service" is assessed). For Boston the savings would appraoch $2.5 million annually.

Next Steps

The conclusions and recommendations discussed above are spelled out more explicitly in Chapter 8 along with the next steps which are likely to be taken in developing a policy toward commuter rail and in implementing these recommendations. In summary, this report has recommended, on the basis of a technical analysis, that substantial sums be invested in improving certain commuter rail lines and that there be a testing period for others, after which decisions about continued operations and investment should be made. This report is only one step in the development of a policy. Additional actions will need to be taken in this regard, including acceptance of this report as a basis for policy by MBTA and EOTC, application for Federal capital funds by MBTA, budgetary actions involving MBTA, EOTC, the MBTA Advisory Board, and the General Court, as well as a citizen review process already begun through JRTC and other groups.

1.0 INTRODUCTION

1.1 HISTORY OF COMMUTER RAIL

The commuter rail network that exists in the Boston area in 1978 is not a monument to the foresight and careful planning of bygone railroaders. Rather, it represents the remaining elements of a patchwork quilt of rail lines that proliferated throughout New England as a product of the colorful era of railroad speculation in the region. The present system comprises pieces of three railroads of the Twentieth Century: The New York, New Haven, and Hartford; the New York Central; and the Boston and Maine. The first two lines became parties to the ill-fated Penn Central merger in the late 1960's. Most of the former lines of these railroads through the Northeast and Midwest have since been acquired by Conrail. The Boston and Maine is now bankrupt but is still a key participant in the provision of the commuter rail service in the Boston area.

1.1.1 Early Development

On most of the commuter rail system, service was at its maximum intensity between 1890 and 1915. During these years, service on each branch was operated from several turnback points, many of them less than ten miles from Boston. For a variety of reasons substantial service reductions on most lines began taking place even before World War I.

Every decade after the 1920's saw decreases both in the number of trains on each route and in the number of routes in service. Even World War II, which resulted in substantial growth in mass transit ridership did not interrupt the overall pattern of service frequency reductions.

Since all of the railroads were privately held and were for-profit organizations, they felt no commitment to retain their commuter rail services when they foundered. To the railroads,who wished to concentrate upon their more profitable freight operations, commuter rail services were a burdensome financial drain and became prime candidates for discontinuance. The railroads' desire to abandon their commuter services complemented a variety of social changes over the first half of the twentieth century - changes that resulted in the reduction and curtailment of such service.

The commuter lines had difficulty competing with the level of service and cost provided by organizations that were solely in the passenger transport business. The shortest routes were unable to match the frequencies of rapid transit lines which

began to open in 1901. The rapid transit lines had the advantage of a large network of connecting street railway lines, most of which were under the same management as the rapid transit system. Commuter rail lines for the most part had feeder service only if streetcar lines happened to connect conveniently. All modes of public transportation were hurt by inflation resulting from the war and by increasing popularity of the automobile during the 1920's.

Although ridership experienced an upturn during World War II, it was only a temporary interruption of a long term downward trend. The post World War II era saw a variety of key events: the continued, growing popularity of the automobile; massive investment of public works funds in roadbuilding, including the Interstate Highway network; and the rapid dispersal of the population throughout heretofore lightly settled suburban areas due to the new highways and the easy availability of mortgage money. The net result of these events, which befell all types of public transportation, was a further decline in ridership. This decline in ridership combined with the reluctance or inability of the railroads to invest capital in their passenger services also contributed to a decline in the level of service offered by the railroads.

A noteworthy turning point in the generally negative foregoing chronology was the controversy over the discontinuance of service on the Old Colony Lines of the New Haven Railroad in the late 1950's. The Old Colony Lines served 700 commuters per day in the South Shore suburbs of Boston. Sufficient public outcry occurred that the Commonwealth became involved. Studies were conducted, and an operating subsidy was provided. Although the service was ultimately abandoned due to the destruction by fire of the railroad bridge over the Neponset River, this issue was significant for two reasons: first, it set the precedent for public involvement in the provision of rail commuter service, second, it illustrated that perhaps commuter lines were a useful and popular service and that continued deterioration and abandonment of these lines was not necessarily a fait accompli.

1.1.2 Development of Commuter Rail Operation Financing

Further public involvement in commuter rail began under the aegis of the Mass Transportation Commission (MTC) in the early 1960's. The MTC conducted experiments which showed that commuters could be attracted back to rail service.

A major objective in establishing the MBTA in 1964 was to provide a mechanism for subsidization of commuter rail service until satisfactory long-term plans could be developed. The first subsidy contract with the Boston and Maine became effective in 1965, and the first contract with the then New Haven railroad the following year.

When the Massachusetts Bay Transportation Authority was organized under Chapter 161A of the Acts of 1964, the General Court provided for an Authority managed Commuter Railroad Financial Assistance Program. This program consisted of equal parts of State funds and Authority funds. The passage of the railroad assistance provisions by the General Court served to forestall the imminent collapse of the railroad commuter service. It was intended to keep the service running for three years through 1967, with 50 percent state assistance.

In 1967 when the funds from the original program ran out, a new allocation was passed which then provided for 90% Commonwealth assistance. Annual allocations continued to be the main source of financing the commuter rail deficit until 1973. The crisis over whether or not the commuter rail deficit would be paid for was an annual event. However, the 1972 allocation showed some signs of an improving status for commuter rail. That allocation provided for 100% state financing of the deficit.

The status of commuter rail changed significantly in 1973. Chapter 1140 provided for the commuter railroad subsidy to be integrated with the MBTA's net cost of service for all other transit operations, i.e., the net cost is assessed against the cities and towns of the MBTA district except to the extent that these costs are reduced by state and federal aid. Another effect of Chapter 1140 was that commuter railroad operations are no longer treated as a separate service for funding the net costs of operation. Thus, all communities which have railroad service are treated the same as all other communities in the MBTA district. The Commuter Rail Department of the MBTA was formed in 1974 to complete the integration of commuter rail into the Authority.

The service continued to be operated by the Boston and Maine and the Penn Central until April of 1976 when ConRail was formed* and thereby assumed all of the former Penn Central commuter operations. In March of 1976, the Authority executed a new five-year contract with the Boston and Maine for operation of the region's Northside services, effective January 1, 1977. In March of 1977, the Authority executed a similar contract with the B & M for operation of the Southside services, effective March 13, 1977 and ending coterminous with the five-year contract mentioned above. The Authority had become dissatisfied with the former operator, Conrail, for what it considers were excessive operating cost estimates and unresponsiveness to local service needs and problems.

During this time, various Federal programs also were initiated to help pay some of the costs of transit deficits. The one most

* As established in the Regional Rail Reorganization Act of 1973.

significant to commuter rail in Boston* provided for transitional, diminishing subsidies for commuter services operated by ConRail from 1976 to 1980 (originally 1978). A similar act provided equity for B&M operated services. In addition to these direct commuter rail subsidies, UMTA has provided general operating assistance to the MBTA, and hence a share of those funds help to support commuter rail.

Table 1-1 shows the trend in subsidies provided for commuter rail services in Boston. Also shown in the table are the various legislative acts which have provided these funds.

1.1.3 Acquisition of, and Capital Improvements to Commuter Rail Facilities

The first mention of plans to acquire commuter rail rights-of-way was in the 1966 Program for Mass Transportation, though this report recommended conversion of numerous lines to rapid transit service. However, more recent plans have been oriented towards upgrading the rights-of-way for improved commuter rail service.

The upgrading of commuter rail began in January of 1973 when UMTA approved an Advance Land Acquisition Loan to purchase 145 miles of Penn Central right-of-way. A capital grant in June 1973 enabled the MBTA to purchase the Reading Branch. The CRIP I Capital Grant in July 1975 and CRIP II Capital Grant in October 1976 provided for purchase of the Franklin Branch and 270 route miles of B&M right-of-way. With conveyance of all of these properties to the MBTA, over 440 route-miles of right-of-way had become available for upgrading with public financing.

CRIP I and CRIP II also provided for the purchase of over 210 units of Penn Central and B&M commuter service rolling stock, and for the first steps in upgrading the rights-of-way and rolling stock. Under these grants, some track work, rolling stock refurbishment and rolling stock purchases have already been performed or contracted for. The CRIP III grant which was recently approved provides additional money for track-work and for the purchase of equipment, as well as money for design and engineering of a new bridge (to replace Draw 7) and a new maintenance facility on the Southside.

This acquisition and improvement program has been underway for over four years and has resulted in the commitment of significant amounts of funds by the Commonwealth and the MBTA. Over $60 million have been spent to purchase the system and over $106 million have been committed to upgrading the system. Table 1-2 shows the sources of these funds.

If commuter rail is to become a reliable, and efficient service to Boston's suburbs, upwards of 200 million to 300 million additional dollars must be spent to upgrade the system.

* Section 17 of the UMTA Act of 1964 as amended by the Railroad Revitalization and Regulatory Reform Act of 1976.

Calendar Year	Total Commuter Rail Deficit			Percent of MBTA Net Cost	Chapter of State Acts	Share Paid by U.S.	Share Paid by State	Share Paid MBTA by Cities/Towns
	Northside	Southside	Total					
1965	$ 3,074,173	$ 773,154	$ 3,847,327	--	--[1]	--	50.0%	50.0%
1966	2,743,232	1,265,125	4,008,357	--	--	--	50.0%	50.0%
1967	2,957,964	1,111,195	4,069,159	5.5%	24	--	90.0%	10.0%
1968	3,252,213	1,038,161	4,290,374	9.9%	728	--	90.0%	10.0%
1969	3,626,102	1,228,985	4,855,087	12.3%	annual[2]	--	90.0%	10.0%
1970	4,083,847	1,601,729	5,685,576	9.0%	annual	--	90.0%	10.0%
1971	3,776,114	1,984,642	5,760,756	7.3%	annual	--	90.0%	10.0%
1972	5,056,443	2,198,958	7,225,401	7.9%	annual	--	100.0%	0.0%
1973	6,063,667	2,769,840	8,833,507	8.3%	1,140	--	50.0%[3]	50.0%
1974	8,327,966	3,400,517	11,728,483	9.1%	825	5%	45.0%	50.0%
1975	10,408,061	4,154,703	14,562,764	9.9%	annual	7%	46.5%	46.5%
1976	13,060,348	4,594,083	17,654,431	10.8%	annual	9%	45.5%	45.5%
1977 (est.)	15,182,877	11,508,899[4]	26,691,776	9.1%	annual	26%	37.0%	37.0%
1978 (est.)	15,487,000	11,731,000	27,218,000	--	--	--	--	--

[1] Chapter 161A of Massachusetts General Laws, as amended by Chapter 563 of the Acts of 1964.

[2] Annual appropriations

[3] State share paid as share of MBTA Net Cost of Service

[4] Penn Central reorganized, new operating contract with ConRail, then B&M. Previously, the ICC had mandated continuation of service, and hence Penn Central was required to internally subsudize the service. Much of the increase due to changed Federal policy is temporarily to be picked up by Federal government (Sections 17 & 18).

TABLE 1-1

COMMUTER RAIL SUBSIDIES

PURPOSE OF GRANT

Grant	Date	Purchase	Loan Retirement	Improvement	Total
PC loan	Jan'73	19,500,000	--	--	19,500,000
CRIP I	Jul'75	250,000	(992,500)	12,391,500	13,634,000
EDA I	Jul'75	--	--	832,212	832,212
B&M loan	Oct'76	24,172,750	--	--	24,172,750
CRIP II	Oct'76	16,177,250	(297,750)	41,411,200	57,886,000
EDA II	Sep'77	--	--	2,500,000	2,500,000
CRIP II	May'78	--	--	23,712,875	23,712,875
CRIP III	Sep'78	--	--	25,000,000	25,000,000
		60,100,000	(1,290,250)	105,838,787	167,229,037
		--		--	(1,290,250)*
TOTAL		60,100,000		105,838,787	165,938,787

*Note: This amount (Loan Retirement) is subtracted from total to prevent double-counting.

CAPITAL GRANTS AND LOANS TO
MBTA COMMUTER RAIL SYSTEM

TABLE
1-2

1.2 OBJECTIVES OF THE STUDY

The aforementioned CRIP I and CRIP II Capital Grants have provided funds for the purchase of Boston's railroad facilities and for some desparately needed upgradings. However, a comprehensive plan for the long term future of commuter rail has not been developed even though various policies have provided for the continuation of commuter rail service. Before further commitments could be made to commuter rail it became necessary to develop a cohesive policy towards commuter rail and its alternatives, and to develop a long-range plan and program.

The objective of the CRIP Plan Refinement Study has been to provide a thorough analysis of commuter rail and other feasible alternatives for transit service to Boston's suburbs, to determine the best alternative for each commuter rail corridor, and to determine whether and in what form the Commuter Rail Improvement Program should be continued.

The long-range plan to be set forth provides a context in which UMTA can evaluate various capital grant applications is consistent with the Federal Transportation Improvement Program (TIP) and the state Program for Mass Transportation (PMT), and provides the basis for various programming and operating decisions within the MBTA.

1.3 CONTENTS OF THE REPORT

Chapter 2 -- provides an outline of the policies which have affected the development of Commuter Rail Improvement Program and a summary of other issues and objectives at the local, state and federal level affecting the analysis of the commuter rail alternatives.

Chapter 3 -- describes the existing commuter rail system including costs, ridership, revenues, service and equipment characteristics and local deficit assessment.

Chapter 4 -- describes the four alternatives designed for this analysis 1) a limited investment system (Plan A), 2) a stabilized system (Plan B), 3) a major restoration system (Plan C), and 4) a commuter bus service system.

Chapter 5 -- analyzes the alternatives on the basis of costs, levels of service, projected ridership, and revenues.

Chapter 6 -- analyzes each alternative, on a line-by-line basis, and determines the most cost-effective system for each line

Chapter 7 -- analyzes the impact of a "composite system" on regional economics, on the environment, and on special needs populations.

Chapter 8 -- presents the findings and recommendations of the study, provides a framework for proposed service experiments, and outlines the next steps required for implementation.

2.0 POLICY CONTEXT OF THE COMMUTER RAIL IMPROVEMENT PROGRAM

Today's commuter rail system is not the result of a careful implementation of public policy. Rather, it is the remains of a system that was built by competing private enterprises, run for whatever profit there might be, then slowly abandoned to public custody. This chapter reviews the various studies and plans that have developed into the present regional policy towards commuter rail.

2.1 PREVIOUS STUDIES AND PLANS

While there was some early regulation of the private railroads, the need for a public policy toward passenger railroad service did not arise until the economic failure of passenger rail service was imminent after World War II. It was at this time that the New Haven and Old Colony Railroads, filing for reorganization under bankruptcy laws, sought to discontinue passenger service on the Old Colony Division, the most heavily used passenger rail line in the Boston area. Eventual discontinuance of other lines seemed inevitable.

The Metropolitan Transit Recess Commission, appointed by the legislature to study rapid transit in the Boston area, stated in its April, 1945 report: "There is no reliable indication that the steam roads will have a place in the improved suburban transportation so vital in the postwar period," except that the railroad rights of way would be used. The commission stated it was "inadvisable to depend on the commutation services of the railroads in the future" and that the railroads should be restricted to providing long-haul passenger and essential freight service, with metropolitan commutation to be provided by an expanded rapid transit system.

As a result of the Recess Commission reports, plans were begun or advanced for replacing railroad service with rapid transit lines. The Boston, Revere and Lynn narrow-gauge railway, abandoned in 1940, was replaced in part by rapid transit by 1954. The New York Central's Highland Branch through Newton was replaced by a rapid transit line (using PCC streetcars) in 1959. Plans were developed for the electrification of the Old Colony Division to Braintree, which was eventually abandoned in 1959 after several years of declining revenues and a brief period of state subsidy.

A new commission appointed in 1957 to examine metropolitan transportation problems held fourteen meetings to air the problem, and reported in January of 1958 that further work should be done to extend rapid transit out over railroad rights of way, while retaining freight service at night. It was thought that this would relieve the railroads of an unwanted burden, and would increase net revenues for the MTA. The report also cited the increased pressure for additional superhighways, and the inability of downtown Boston to handle additional "rubber-tired" traffic, including additional bus traffic, which would be caused by replacing railroad service with bus routes.

In 1959, the legislature appointed a Mass Transportation Commission to study improvements to the facilities and management organization of mass transportation in the Boston region. Sufficient funds were provided to hire planning and engineering consultants and other staff. A major part of the MTC's work included a demonstration of service and fare changes on the commuter rail system. This demonstration showed that service changes (frequency, etc.) can significantly improve patronage on the commuter rail system, while moderate fare increases would have little negative effect on ridership. Another product of the MTC studies was new legislation creating in 1964 the Massachusetts Bay Transportation Authority to replace the Metropolitan Transit Authority. The MBTA was given new powers, including authorization to subsidize commuter rail service, with $10 million provided over three years for this purpose. One of the goals of the subsidy was to keep the commuter rail lines operating long enough to replace some of them with rapid transit lines, but the MBTA was given the option to select which commuter rail lines would be kept open.

The MBTA, in accordance with its original mandate, produced a Program for Mass Transportation in 1966. The program described a list of "Action Projects" which would substantially upgrade and extend the rapid transit system. Many of these projects--the extension of the Red Line south to Weymouth, the extension of the Orange Line north to Oak Grove, and the extension of the Green Line north to Washington Street in Somerville, and the extension of the Orange Line southwest to West Roxbury --would use existing or abandoned railroad rights of way, replacing commuter service on all or parts of those lines. Significantly, however, the program called for the retention, for the time being anyway, of the remainder of the commuter rail system. In some cases, this service would end at a suburban rapid transit station, requiring a transfer at that point to rapid transit. The integration of commuter rail service into the rapid transit system, rather than replacement by rapid transit, marked a new policy toward commuter railroads. However, the program recognized that any long-term resolution of the commuter rail service issue would have to wait for such other events as the reorganization of Northeast railroads being considered at the time, and proposed negotiations for purchase of railroad rights of way and equipment.

In hopes of resolving the open questions on suburban service, the legislature in 1968 directed the MBTA to submit to the MBTA Advisory Board an analysis of at least three alternative programs for providing service to the communities served by commuter railroads. The MBTA submitted these three programs and its recommendation in January of 1969. The MBTA recommended Plan C which would operate a combination of railroad and bus service, with contract railroad service cut back to the area within Route 128.

The recommendation was a departure from previous policy. Whereas previously the role of commuter rail had been to serve the outer suburbs with long, line-haul runs, the new policy seemed to be to have the railroads operate in the rapid transit service area, with buses to handle the suburban communities. The new policy was not well received; the Advisory Board refused to endorse the recommended program. A special comission appointed by the Governor to study the finances and organization of the MBTA reported in July, 1969 that it endorsed a full-commuter rail system, except for the Reading and Needham lines which were to be replaced by rapid transit.

Other plans and studies were not so clear in their treatment of commuter rail. The Eastern Massachusetts Regional Planning Project (EMRPP) recommended only that commuter rail service be continued under subsidy until final plans were formulated. A 1969 MBTA study examined the feasibility of dual-powered rail vehicles for use on commuter rail lines.

The Governor's transportation restudy project--the Boston Transportation Planning Review--further examined commuter rail and in Governor Sargent's policy statement in November, 1972, recommended, a $70 million dollar program to modernize and upgrade the commuter rail system. In this speech, the governor stated that transit would take on a larger role in providing transportation in the metropolitan area, and improved commuter rail would be part of that transit system.

At approximately the same time, Thomas K. Dyer, Inc. completed for the MBTA a "Plan for Acquisition and Use of Railroad Rights of Way". This report recommended the acquisition of railroad rights of way in the metropolitan area and again recommended dual-powered vehicles, a concept which has made little progress. The recommendations on acquisition of rights-of-way, however, assisted in the acquisition of Penn Central properties in 1973 and Boston and Maine properties in 1976.

Since 1972, transportation planning in the Boston Region has been conducted through a continuing, comprehensive process in a cooperative manner by the various transportation agencies. This "3C" process has resulted in an annual updating of transportation plans, including plans for improvement to the commuter rail system. The first such program, the 1973 Five Year Transit Development Program, included $50 million for right-of-way

acquisition and $90 million for upgrading of the commuter rail system. At that time, the commuter rail program included the electrification of several routes as recommended by the Dyer report, in addition to track, roadbed, station, parking, and maintenance facilities.

The 1974 Transit Development Program included $100 million for commuter rail improvements over a 10 year period, although this amount excluded lines that were to be electrified and integrated into the rapid transit network. Instead, these electrification projects were included on their own. The 1975 and 1976 Transit Development Programs included approximately $100 million in commuter rail improvements, with two specific projects singled out: $13.6 million for improvements on the Franklin Branch, and an unspecified amount (which later turned out to be $39.6 million for purchase of the B&M rights of way and equipment. These Transit Development Programs received extensive agency and public review, as the product of the cooperative planning process, indicating that public policy was to retain an improve commuter rail service as part of the public transportation system in the Metropolitan area.

During this time, the MBTA continued to work on specific elements to be included in the Commuter Rail Improvement Program. This effort resulted in the CRIP I application (improvements to the Franklin Branch), approved by UMTA in 1975. An engineering report issued in 1976 detailed $283 million in commuter rail improvements necessary to bring the system into maximum operating efficiency. This program represented a major increase in the level of investment in commuter rail.

The $283 million program (which was in addition to the $13.6 million already approved) was fully analyzed for the Draft 1977 Program for Mass Transportation and the Technical Supplement to the PMT. This analysis included an examination of alternative suburban service, and eventually resulted in the inclusion of the full project in the 1977 PMT. This document was drafted by the Executive Office of Transportation and Construction and received extensive public review. The document has been prepared with the cooperation and review of the Transit Development Committee of the Advisory Board. The document was submitted for final action by the Advisory Board on November 27, 1978.

The 1977 Transportation Improvement Program (the multi-modal successor to the Transit Development Program) followed the analysis of the 1977 PMT and included the full upgrading program to be funded over a ten-year period. In October 1976, a $57.9 million CRIP II application had been approved by UMTA. The 1977 TIP was endorsed by the major transportation agencies acting as the Metropolitan Planning Organization, and is recognized by the Urban Mass Transportation Administration as the officially endorsed transportation program for the Boston region

2.2 CURRENT POLICY

2.2.1 Policy Towards Commuter Rail

The current policy toward the commuter railroad system is contained in the reports and planning documents which establish the program for transportation improvements in the Boston region. The most important of these documents are the Transportation Improvement Program, revised annually, and the Program for Mass Transportation (PMT), revised in 1978.

One tenet of this policy is that the commuter railroad system is a valuable physical resource that should not be allowed to deteriorate any further. It would be prohibitively expensive and disruptive to acquire rights-of-way comparable to those which now exist on this system. In the recent past, these rights-of-way have been underutilized because service levels and equipment have deteriorated.

Secondly, transportation decisions of the past eight years have steered the Boston Metropolitan Area away from a reliance on the automobile and toward an increased use of public transportation; away from dispersed activity, and toward concentration of activity in the regional core. The decisions not to build additional expressways within Route 128 and to limit parking in core areas mean that the highway system cannot accomodate any growth in suburb-to-core traffic. This growth will have to occur on the public transportation system. At the same time, the decreasing availability and increasing price of gasoline will make automobile travel less attractive to the commuter.

Thirdly, there is a new awareness of the need to integrate transportation facilities and modes in order to get the most out of each. In this light, the commuter rail system is seen as a complement to the rapid transit and bus and highway networks, rather than as a competitor with them. Studies, such as the 1977 Technical Supplement to the PMT, have shown that, for certain geographic markets, upgraded commuter rail service can be provided at less cost than rapid transit and more effectively than bus service. It is clear that each of these modes plays an important role in the transportation system.

These factors have resulted in a public policy favoring significant investment in the commuter rail system to modernize it and make it as efficient as possible. This investment is intended to increase ridership and to reduce the per-rider operating costs of the system.

2.2.2 Other Regional Policies

The primary goal of the Commuter Rail Improvement Program is to upgrade the quality of service and at the same time control the costs of providing service. This goal involves both

the maintenance and improvement of existing facilities. Such measures would help to ensure the efficient operation and stability of service as well as increasing the comfort, convenience and reliability of the existing system. These actions would help the system retain present riders and encourage new riders in commuter rail market areas.

Other objectives relate to social and environmental concerns. The commuter rail program seeks to comply with federal environmental regulations. It also will endeavor to introduce the use of energy conservation measures as well as to facilitate the use of the system for those individuals with limited mobility.

The commuter rail system can also have a positive impact on the region's economic well being. Improvements to the system would reinforce the attractiveness of the core area for development and promote the growth or redevelopment of other activity centers in the service area. Furthermore, the use of rail rights-of-way by both freight and commuter service indicates that a mutually beneficial relationship between the two would enhance the region's economic vitality.

2.2.3 New Emphasis in Policy

To this date, the Authority has invested about 100 million dollars in the Boston Region's commuter rail system. The commitment to retaining and improving the commuter rail network is clear, backed by obvious fiscal action. The CRIP Plan Refinement Study represents by far the most thorough and sophisticated attempt to forecast the system-wide financial demands inherent in a permanent commitment to commuter rail. The capital cost inventory undertaken as part of "Plan C" was compiled with the technical input of a wide variety of specific consultant and in-house project development efforts. The scale of investment implied in "Plan C," when viewed in the context of limited foreseeable capital resources, mandates a new policy context for commuter rail investment: resources must now be carefully allocated among condidate investments.

Up to the present time, the Authority and the Commonwealth have been able to make investments which are essentially defensive in nature - the rights of way had to be purchased to be preserved, emergency up-grading had to be accomplished in order to continue service, rolling stock had to be replaced in order to have any vehicles whatsoever. These types of investments were not particularly appropriate for detailed alternatives analysis - having appeared as a string of fiscal emergencies. The majority of investments to this point, such as right of way purchases,emergency upgradings, and rolling stock have been consistent with all proposed long-term rail configurations. The program has now reached a juncture where careful allocation of resources must take place among project alternatives. This volume, the CRIP Plan Refinement Study,

fully acknowledges that reality.

The technical work accomplished to date makes it clear that all lines are not equally suited for improvement through capital investment. The structure of this study has been designed to reveal differing levels of improvement stemming from differing levels of capital investment. The need for substantial capital improvements to the Eastern Route (e.g. Plan C data) can be contrasted with the case of the Framingham Line, where policy questions focus on operating rather than capital issues. Given these facts, the allocation of scarce capital resources over the separate elements of the system must be guided by careful technical analysis of the foreseeable impacts of the investment.

A program which until now has been aimed at general survival and emergency reconstruction must now be refocused to become a program which makes investments prioritized by their cost-effectiveness. A program of providing equal capital treatment to all lines can be shown to be less cost-effective than a program which concentrates capital resources where they will have the most beneficial impact. The CRIP Plan Refinement Study has been created as a first step in this capital prioritization effort.

The detailed costing effort undertaken in the analysis of Plan C emphasizes one other aspect of a new policy context--the necessity of concentrating efforts on existing services and existing markets. Capital is scarce, and the requirements for upgrading the existing system are of such a scale that serious contemplation of possible service extensions must be delayed unless sources of capital can be found which are not available for other MBTA projects. Further, the MBTA's commuter rail rolling stock is aged, and new equipment will not be available as rapidly as once expected.

This policy does not rule out the possibility of some additional services being added over the next few years. Rather, it is an acknowledgement of the reality that such a service will have to be proven effective in a capital evaluation climate where the back-log of desirable projects is already considerable, and the competition among projects for limited capital funds is severe. Candidate projects for system expansion during the next five years will have to be analyzed in this critical light.

Along with the evolution of new policies for commuter rail, the evolving difficulties with committed rapid transit extensions places an increasing emphasis on commuter rail. Even though it was at one time the MBTA's policy to extend rapid transit to Route 128 in almost all corridors, the escalating costs, the decreasing availability of funds for additional

major rapid transit extensions, and the community response to the potential for rapid transit have encouraged the MBTA to seek other means of providing effective suburban service. Commuter rail and, in some cases, commuter bus fit well into this evolving scenario.

3.0 EXISTING CONDITIONS

3.1 SUMMARY

This chapter describes the existing conditions on the commuter rail system as of January 1977 and the trends of the past 10 years that have brought the system to that point.

Between 1966 and 1976, the number of passengers carried by the Northside Lines* decreased by 33 percent, from 6.78 to 4.54 million, and the number carried by the Southside Lines* increased by eight percent, from 2.10 to 3.02 million, resulting in a 21 percent system-wide decrease in the number of passengers carried. With the exception of the Fitchburg Line, where ridership increased by three percent, from 768,000 to 794,000, all Northside Lines experienced a decrease in riders. However, passenger volumes of each of the Southside Lines remained fairly stable. The Franklin Branch, which experienced a 32 percent increase, from 428,000 to 565,000, was the only exception. The results in 1977 have shown a reversal of this decline. On the Northside, ridership for the year was up 2.5 percent, and on the Southside it was up 5.2 percent. The number of passengers carried systemwide increased by 250,000, or 3 percent.

Market size and market capture varied significantly by line in the period from 1963 to 1976. The change in total number of work trips to downtown from the market area of each line ranged between an increase of 2510 trips in the New Hampshire Division market area (from 4460 to 6970 trips) and a decrease of 163 trips in the Reading Branch market area (from 6783 to 6620 trips). In terms of the ability to capture these trips, the Boston & Providence and Stoughton Branch were the most successful, showing an increase of 220 trips. The New Hampshire Division was the least successful in terms of market share, capturing 27 percent less of its market in 1976 than in 1963 (752 fewer trips). (The 27 percent decrease in market capture does not mean a decrease of 27 percent in the number of commuter rail riders, since the total market increased by 56 percent.) The Reading Line experienced the largest actual decrease in trips captured, from 2917 trips in 1963 to 1390 trips in 1976 (a decrease of 1527).

*"Northside" and "Southside" refer to all lines terminating at North Station and South Station, respectively.

The vast majority of trips on the commuter rail system are work trips made on a daily basis by non-captive white collar workers whose destinations are in the financial/retail district. In 1976, 70 percent and 80 percent of all trips were work trips on the Northside and Southside. Forty-eight percent of Northside riders and 53 percent of Southside riders live in households that own two or more cars (only seven percent of Northside and three percent of Southside riders belong to households which own no autos at all).

Twenty-eight communities account for 86 percent of the Northside riders, and eight of these account for over half. On the Southside, 25 communities contain 92 percent of the riders, while eight alone account for over half of the riders.

The most frequent Northside service is provided on the inner portions of the Eastern Route and the New Hampshire Division. The most frequent Southside service (both peak and all day) is provided at Route 128 and Canton Junction stations on the Shore Line. The system-wide average trip length is 16.7 miles.

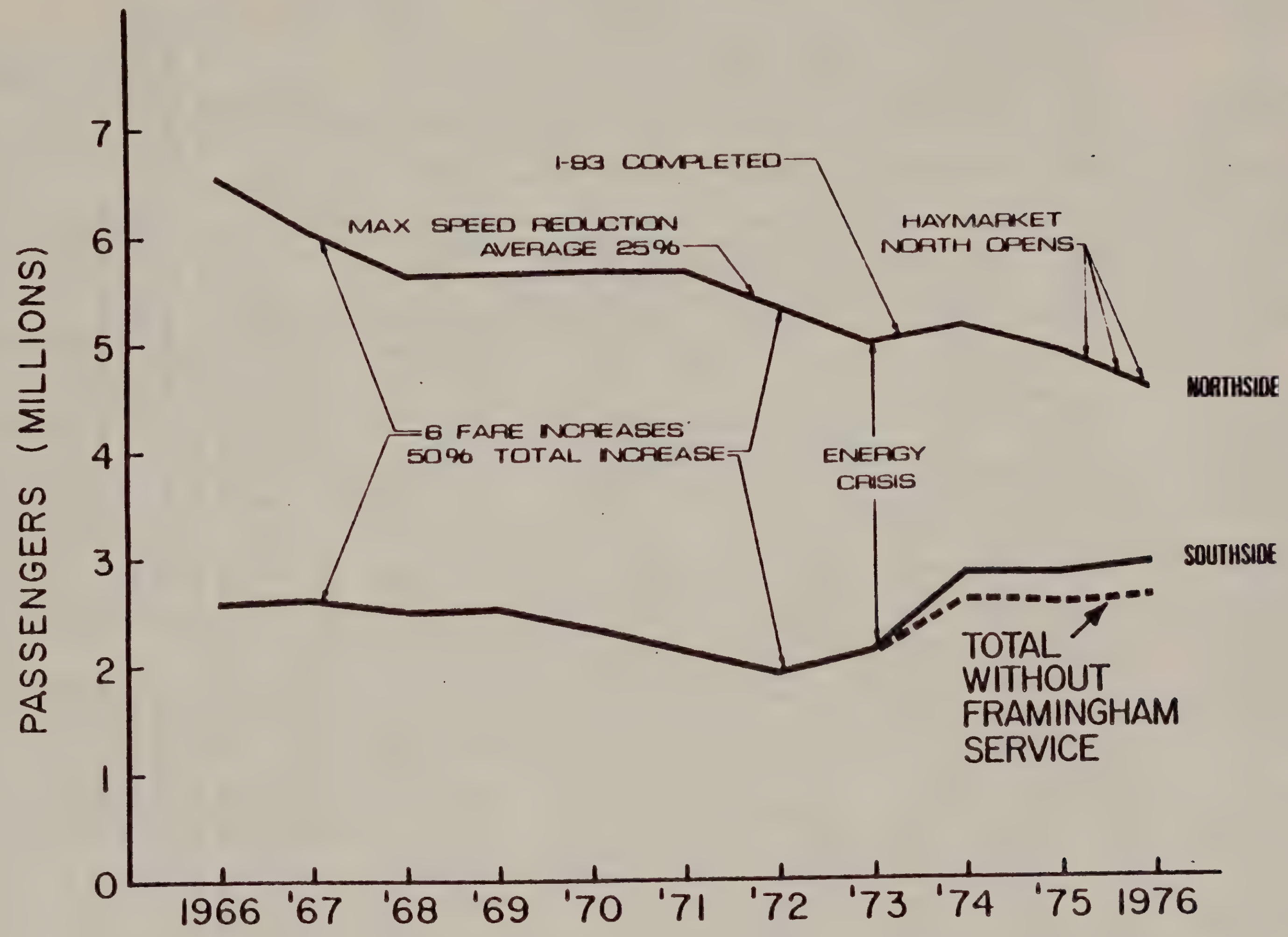
At the present time, there are eleven lines and branches with a total of 379.3 miles of track (201.8 road miles), and 77 stations. Maintenance activities are performed in four different locations. The presently operated rolling stock includes 25 locomotives, 112 coaches and 92 Budd cars (self-propelled "RDC's").

3.2 RIDERSHIP

3.2.1 System-wide Trends

Total passengers carried on the Northside (Boston & Maine) and Southside (Penn Central/ConRail) commuter rail services for the years 1966-1976 are shown in Figure 3-1. Over this period, Northside services exhibited a decrease in passengers of 31 percent, from a 6.6 million to 4.5 million, while Southside services exhibited an increase in passengers of 3.8 percent, from 2.6 million to 2.7 million; the assumption of the Framingham service of the Penn Central by the MBTA in 1974 (at that time the service went to Worcester) adds another 0.3 million to the Southside totals. Some of the decrease in Northside ridership can be attributed to the elimination of service to several communities since 1975.

On the Northside services, ridership decreased by 63 percent (from 18 million to 6.6 million riders annually) from 1950 to 1966. Over that period, the Southside ridership decreased by 70 percent (from 15 million to 4.5 million). These estimated figures include inter-city trips which were much more frequent in 1950 than in 1966. The 10-year trend of declining commuter rail ridership has been reversed



TEN-YEAR RIDERSHIP TRENDS

FIGURE
3-1

over 1977, particularly on the Northside, where there has been a resurgence in ridership. Table 3-1 shows these trends. Prior to 1972, ridership had been declining steadily both on the Northside and Southside commuter rail lines. This decline had continued, though to a lesser degree, on the Northside, while on the Southside patronage began to increase annually with the most dramatic increase occurring in 1973, the year of the energy crisis. The continued growth trend on the Southside* has resulted in a 4.3 percent increase in total ridership in 1976 and a 5.2 percent increase in 1977.

3.2.2 Line Volumes

Line-by-line passenger volumes for the commuter rail service in the Boston area are shown in Figure 3-2. As was mentioned earlier in this chapter, Northside ridership for the period 1966-1976 generally declined. All Northside lines experienced a decrease in ridership, with the exception of the Fitchburg Line, which experienced an increase of 3.3 percent over the period 1966-1976. The decreases by line for that period were as follows: Eastern -- 19 percent, New Hampshire -- 28 percent, Reading -- 40 percent. Part of this decline can be attributed to the steady deterioration of the physical plant and to the decrease in service. Competition from I-93 and from the Haymarket North extension of the Orange Line also played a major role. Over the last four years, with the exception of energy-plagued 1973, total ridership on the Northside continued to fall off annually until 1977, which has seen a 2.5 percent increase in ridership through November; the Eastern and Fitchburg rail lines showed increases of 11.6 and 3.0 percent, respectively. This reversal is quite significant in view of the 10.2 percent drop in ridership that occurred during the previous year. Ridership has continued to fall on the Reading and New Hampshire lines during 1977, but the rates of decline have diminished considerably from those of 1976.

By contrast, passenger volumes on Southside Lines were generally stable over the period 1966-1976. The Franklin Branch experienced an increase in passenger volume of 32 percent over that period, the largest increase of any single line. Changes on other lines during this period were as follows: Providence -- no change, Needham -- 6.6 percent, Stoughton -- 16 percent. Data for the Framingham Line were not included since the 1976 information was the first full year of ridership data available for this line.

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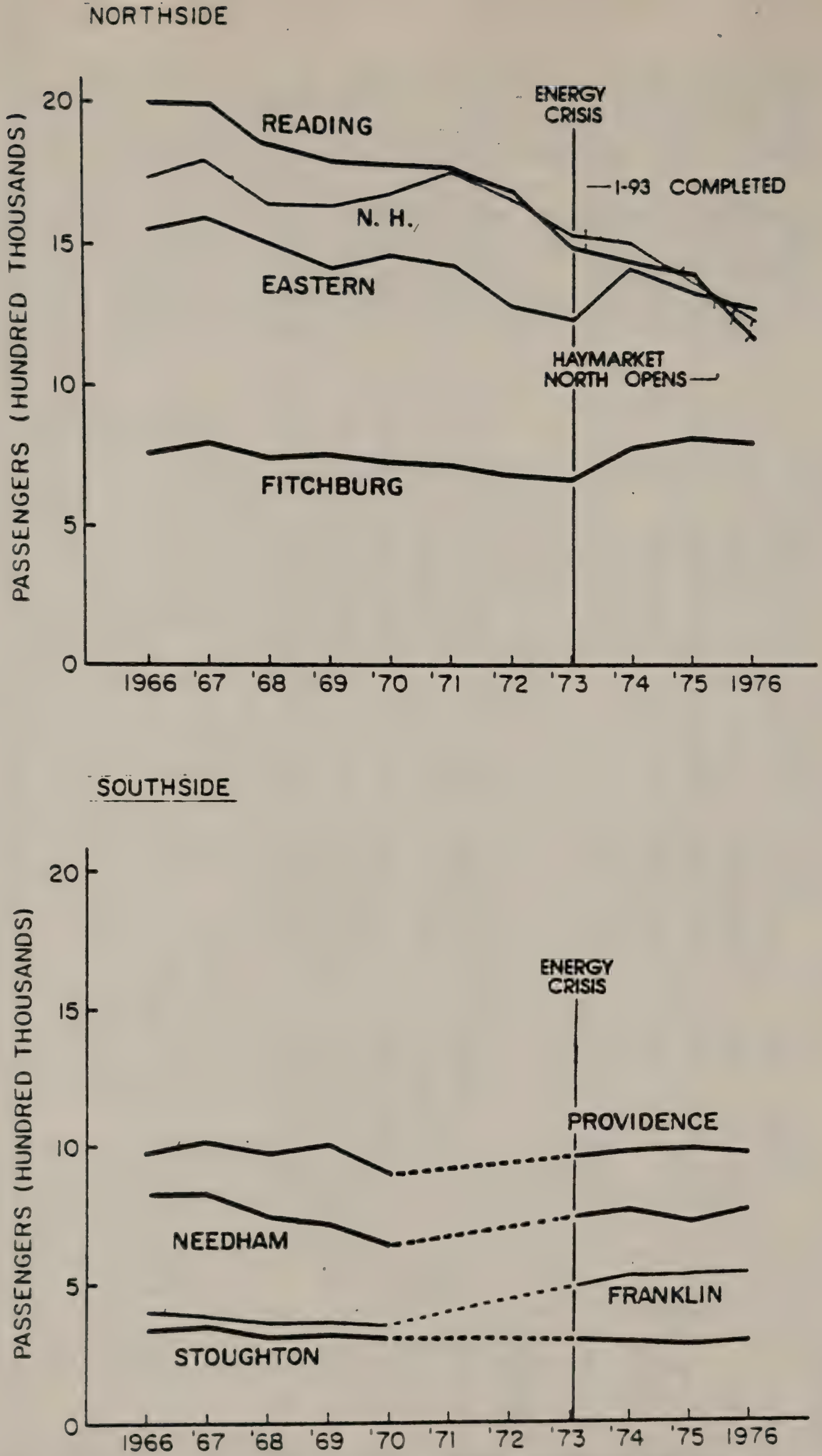
*The Southside data does not include cash fares; estimates of the number of cash fares run as high as 20 percent of the total.

		1975		1976		1977*	
	Total Ridership 1974	Total Ridership	% Change	Total Ridership	% Change	Total Ridership	% Change
Northside Service							
Eastern Line	1,440,995	1,380,763	-4.2	1,278,790	-7.3	1,413,683	+10.4
Reading Line	1,474,730	1,422,531	-3.4	1,210,264	-15.0	1,193,343	- 1.5
New Hampshire Line	1,546,525	1,411,866	-8.7	1,256,753	-12.3	1,224,477	- 2.8
Fitchburg Line	790,765	833,153	+5.3	793,749	- 5.0	815,069	+ 3.0
Total Northside	5,253,015	5,048,313	-3.9	4,539,556	-11.2	4,646,572	+ 2.5
Southside Service							
Framingham Line	313,935	313,280	-0.2	325,515	+ 4.0	353,079	+ 9.2
Needham Line	768,728	772,767	+0.5	770,030	- 0.4	747,604	- 3.2
Franklin Line	526,872	531,346	+1.0	565,300	+ 6.3	602,465	+ 7.0
Providence & Stoughton	1,278,576	1,279,781	+0.1	1,360,729	+ 6.3	1,461,207	+ 8.1
Total Southside	2,888,111	2,897,174	+0.3	3,021,574	+ 4.3	3,164,355	+ 5.2

*First 11 months of 1977, annualized

TABLE 3-1

RECENT RIDERSHIP TRENDS



TEN-YEAR RIDERSHIP TRENDS, BY LINE

FIGURE 3-2

The individual Southside rail lines have all shared in the recent growth trend, with the exception of the Needham Line, which was down 0.5 percent in 1976 and has dipped another 3.2 percent during the first eleven months of 1977.

3.2.3 Distribution of Inbound Boardings by Station

Inbound boardings by commuter rail station were examined for November 1976, the date of the comprehensive survey of commuter rail users. The results of this analysis are depicted in Figure 3-3.

As can be seen in the Figure, there is a wide variability in boardings by station, even along the same line. Out of 44 Northside stations, there are five stations where more than 300 patrons board daily, and there are twelve stations that are used by less than 25 riders per day. These differences are largely explainable by differences in parking supply, availability of alternative modes, and station accessibility.

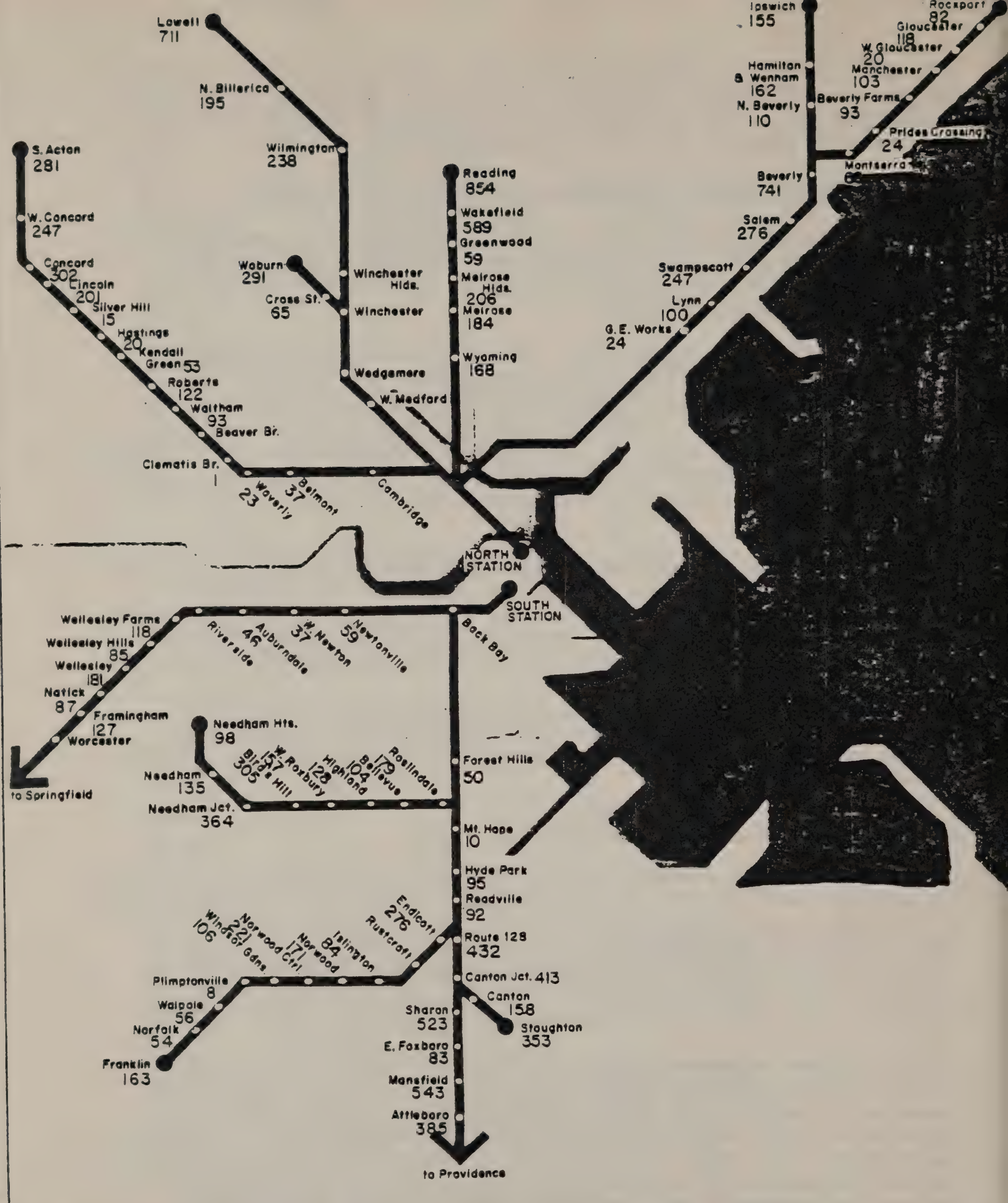
Average weekday boardings for the Southside service are also depicted in Figure 3-3. Out of a total of 41 Southside stations, eight stations had more than 300 weekday boardings. Excluding Worcester (where service is no longer offered), only five of the recorded stations had less than 25 boardings.

In summary, recent growth in ridership of 5.2 percent on the Southside and 2.5 percent on the Northside seem to indicate a turnaround in the response of the public toward commuter rail service.

3.2.4 Impacts of Service Improvements

Several schedule changes were initiated on October 31, 1977, improving service on the Framingham, Franklin, Stoughton and Fitchburg commuter rail lines. In one form or another, these changes consisted of extended service periods (peak or off-peak), reduced headways during the current service period, and reduced headways along with improved travel times. Table 3-2 shows the results of these improvements.

Of the three types of service changes, added service at a time outside the then existing hours of service elicited greatest response in terms of new ridership (Stoughton). Apparently the earlier peak hour departure time proved more convenient for many who previously opted for other modes rather than wait for a later train. Other peak hour improvements (in headways and travel times) showed some gains; however, expanding the time period of service at the peak hour proved to have the most significant impact. The following examines the impacts line by line.



1976 Commuter Rail Survey

AVERAGE WEEKDAY COMMUTER RAIL PASSENGER BOARDINGS

FIGURE 3-3

	Type of Schedule Change	Annual Trend			Annual Trend plus Schedule Change			% Change due to Schedule
		Oct.'76	Oct.'77	% Change	Nov.'76	Nov.'77	% Change	
New Hampshire (Inbound Peak)	none	24,296	25,164	+ 3.5	22,839	23,645	+ 3.5	0.0
Fitchburg (Inbound Peak)	headway, travel time	14,278	14,843	+ 3.9	13,931	14,498	+ 4.0	+ 0.1
Framingham (Outbound Peak)	extra train (safety valve)	11,789	14,061	+19.3	11,506	14,009	+21.8	+ 2.5
Franklin (Inbound Peak)	headway, travel time	21,253	20,937	- 1.5	19,649	21,585	+ 9.8	+11.3
Franklin (Outbound Peak)	headway, travel time	19,453	19,314	- 0.7	18,096	20,831	+15.1	+15.8
Providence (Inbound Peak)	headway, travel time	31,754	33,231	+ 4.6	29,441	31,598	+ 7.3	+ 2.7
Providence (Inbound Off-Peak)	headway	6,421	6,825	+ 6.2	6,137	7,207	+17.4	+11.2
Providence (Outbound Off-Peak)	headway	8,370	8,053	- 3.8	8,147	8,738	+ 7.3	+11.1
Stoughton (Outbound Peak)	extra train	10,539	11,191	+ 6.2	9,960	16,143	+62.0	+55.8

TABLE 3-2

IMPACTS OF RECENT SERVICE CHANGES ON MONTHLY BOARDINGS

Ridership changes were computed in terms of percent change between the month prior to the improvements and the month following, accounting for both monthly and yearly variations in ridership by comparing with the same months in 1976. The change exhibited between the two Octobers shows the 1976-1977 variation, while any increment over that amount shown in November represents the growth resulting from the service improvements.

A "safety valve" train on the Framingham Branch departing 1½ hours after the evening peak attracted an additional ridership of 2.5 percent.

Service changes initiated on the Franklin Branch included the addition of one inbound train during the morning peak period and one outbound train during the evening peak period, which increased ridership by 11.3 percent and 15.8 percent, respectively. A third train was also added to the evening peak out-bound service on the Stoughton Branch; it increased ridership by 56 percent.

Several changes were initiated on the Providence Line affecting both peak and off-peak service. A fourth train was added to the inbound morning peak schedule, with a resulting ridership increase of 4.3 percent. Additional service changes were initiated on the Shore Line affecting mid-day service between Attleboro and South Station. Headways were reduced from two hours to one hour, and two station stops were added. The response to the added service has been quite positive, with mid-day ridership up 11.2 percent.

The final line incurring a schedule change was the Fitchburg Line, which is part of the Northside service. An additional outbound train was run express from North Station. The results of this service change proved to be inconsistent with other lines. Despite the service improvements, ridership did not increase. The only impact of the added service was that ridership was divided among the three earlier trains rather than between two. One possible explanation for this lack of response is that headways on the line were superior to the other upgraded lines under the old scheme. As a result, minor schedule changes would not have the same impact on the Fitchburg Line as was exhibited on the other lines. Another possible factor is that the existing demand was adequately served, so that further improvement would not attract additional ridership.

In summary, with the exception of the Fitchburg Line, the recent service changes did attract additional ridership during the affected schedule period. The results, then, suggest that commuter rail can attract new ridership when service improvements are geared to the travelers' needs.

3.3 DESCRIPTION OF USERS

3.3.1 Overview

Most commuter rail riders are professionals or clerical workers who own one or more cars and have an average family income of nearly $20,000. They use commuter rail almost every day and usually for going to or from work. Their trip to the station is usually by car, though many walk, and most riders get to their destination in the financial district or government center by walking from one of the downtown stations. The origins of commuter rail riders are in numerous cities and towns, but 16 towns account for over 50% of users and 2 towns (Beverly and Needham) account for over 10%.

The overview given above highlights the most common characteristics of the rail patron. But, it only tells part of the story. Details on user characteristics are shown in the following sections.

3.3.2 Trip Characteristics

As mentioned in the overview, most commuter rail trips are work trips (73 percent on the Northside and 87 percent on the Southside). This is primarily due to the radial* nature of the service and to the schedule of trains. The Northside service exhibits a lower work trip percentage than the Southside service due to the better off-peak service offered on the Northside lines. The "school" and "other" categories of trips on the Northside are better served by off-peak trains, and hence, account for the difference. The combined percentage for the Northside (11 percent for morning peak, 27 percent for all day) is significantly higher than for the Southside (eight percent for morning peak, 11 percent for all day). Table 3-3A shows these results.

As Table 3-3B shows, the park-ride, kiss-ride and walk modes of access together account for at least 95 percent of all passengers. Data also show that for morning inbound trips, almost two-thirds of riders get to the station by car and almost one-third walk. Further, the survey shows more park-riders than walkers in the morning peak. Those who reach the station by bus, taxi or bicycle constitute no more than 1.5 percent in each category. The "All Day" numbers show a large increase in the number of walkers to stations. This is due to the predominance of walking as an access mode to the downtown stations (for outbound trips). On the Northside, 54 percent of all trips from downtown are accessed by walking. On the Southside, this number is 86 percent.

*All lines terminate in downtown Boston.

TABLE 3-3

CHARACTERISTICS OF COMMUTER RAIL RIDERS

A. TRIP PURPOSE

	NORTHSIDE		SOUTHSIDE	
CATEGORY	AM Peak Inbound	All Trips	AM Peak Inbound	All Trips
Work	88.2%	72.9%	91.5%	86.7%
Shop/Personal Business	0.4	2.9	0.3	1.4
School	8.9	13.8	6.9	8.3
Other	2.5	13.4	1.3	3.6
TOTAL	100.0%	100.0%	100.0%	100.0%

B. MODE OF ACCESS

	NORTHSIDE		SOUTHSIDE	
CATEGORY	AM Peak Inbound	All Trips	AM Peak Inbound	All Trips
Park-Ride	42.1%	19.4%	46.0%	23.6%
Kiss-Ride	25.0	13.2	21.8	11.7
Bus	0.2	1.9	0.6	0.7
Taxi	0.7	1.6	0.3	0.3
Bike	0.6	0.4	0.2	0.1
Walk	31.2	44.8	30.7	58.8
Other	0.2	18.7	0.4	4.8
TOTAL	100.0%	100.0%	100.0%	100.0%

C. TRIP FREQUENCY

	NORTHSIDE		SOUTHSIDE	
CATEGORY	AM Peak Inbound	All Day	AM Peak Inbound	All Day
Daily	87.6%	74.7%	91.4%	86.4%
1-3 times/week	9.1	14.1	6.5	9.4
Infrequently	3.3	11.2	2.1	4.2
TOTAL	100.0%	100.0%	100.0%	100.0%

D. VEHICLES PER HOUSEHOLD

CATEGORY	NORTH	SOUTH
0	7.0%	2.5%
1	44.3	43.4
2	36.4	41.1
3 or more	12.3	13.0
TOTAL	100.0%	100.0%

E. LICENSED DRIVERS PER HOUSEHOLD

CATEGORY	NORTH	SOUTH
0	2.3%	1.0%
1	14.7	11.4
2	50.9	56.4
3	16.3	15.8
4	9.9	10.0
5	3.8	4.0
6 or more	2.1	1.4
TOTAL	100.0%	100.0%

Table 3-3C presents trip frequency data for rail patrons. The vast majority of all trips are made on a daily basis. Seventy-five percent of all trips made on the Northside are made daily, 86 percent on the Southside. One noteworthy observation from Table 3-3C is that Northside service had a relatively large response in the "1-3 times/week" and "infrequent" categories -- 9.1 percent and 3.3 percent, respectively, for morning peak, and 14 percent and 11 percent for all day.

3.3.3 Socio-Economic Characteristics

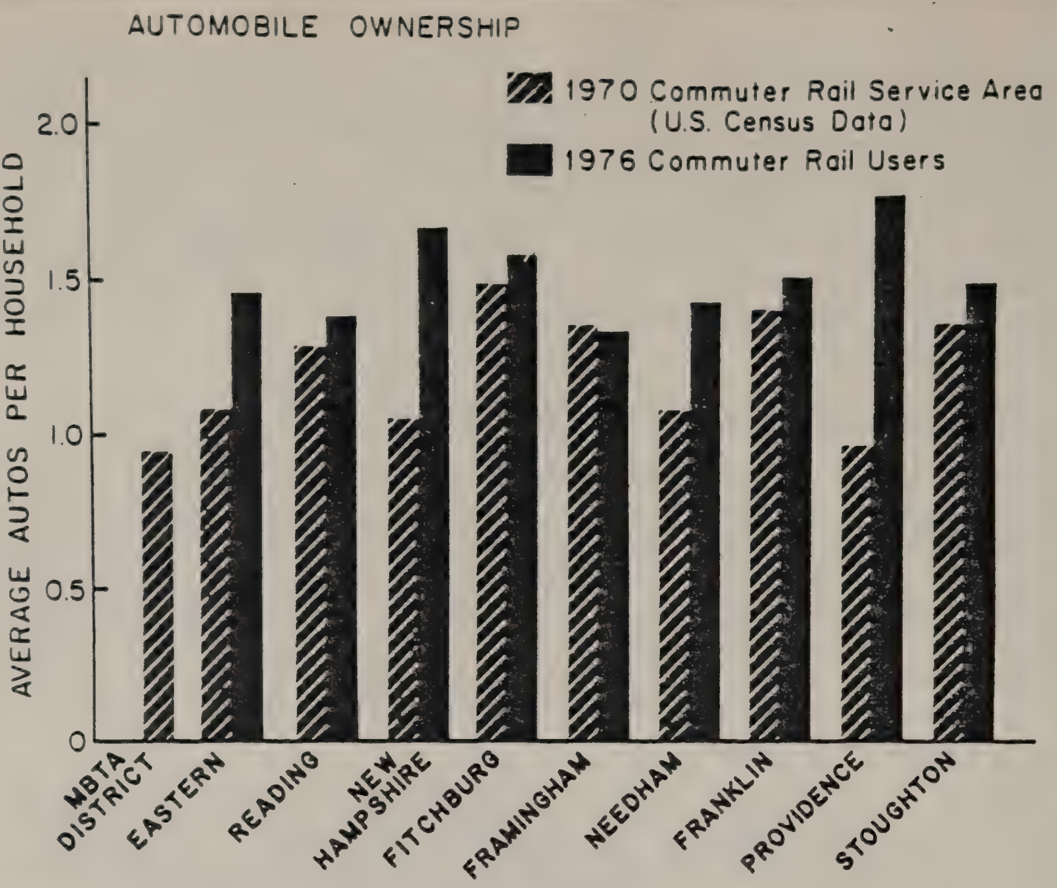
Table 3-3D illustrates the distribution of vehicles per household among commuter rail riders. Only seven percent of Northside riders are from households with no cars, 2.5 percent on the Southside. There is also a high incidence of multiple auto ownership per household: 48 percent of respondents on the Northside service belong to households that own two or more autos; on the Southside, this number is 54 percent. In sum, most of the commuter rail patrons are not captive riders.

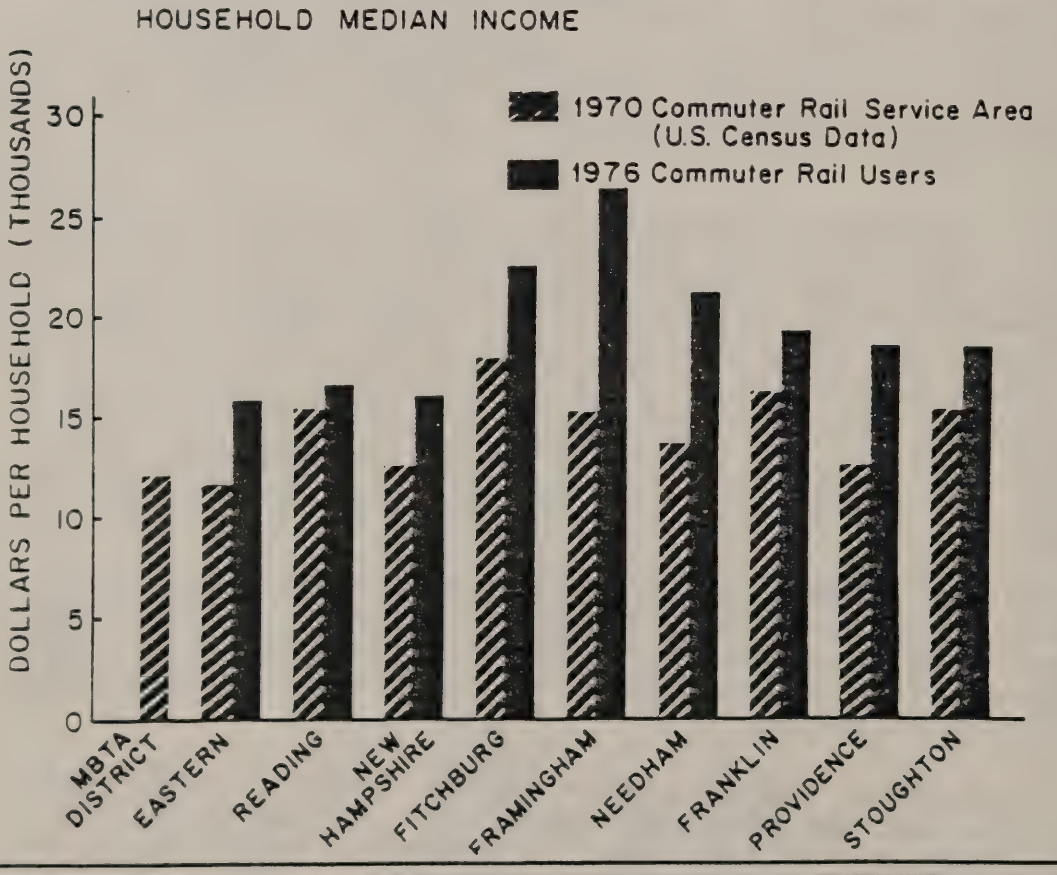
Table 3-3E shows the number of licensed drivers per household of those responding to the CRIP surveys. 81.8 percent of the Northside respondents and 86.8 percent of the Southside respondents reside in households with two or more licensed drivers. The number of respondents' households with no licensed drivers is nearly insignificant--2.3 percent of the Northside households and 1.0 percent of the Southside households.

Figure 3-4 shows a comparison between the auto ownership characteristics of commuter rail users and of the whole population in the service area of each line. It is interesting to note that commuter rail users have more cars than the general populace in all service areas but one (Framingham Line). Some lines show a significant difference, which is reflected in the income characteristics (Figure 3-4). Framingham is an exception. This may be due to the limited service, the limited number of riders, or the impact of good transit service in Newton.

Figure 3-4 shows a comparison between the median income levels of commuter rail users and of service area residents. Again we see that commuter rail users seem much different from the residents of their service area. They have higher incomes.

When comparing the residents of the commuter rail service area and the system's users with residents of the MBTA district, we see that, in general, residents of the MBTA district have fewer cars and less income. This is undoubtedly due to the fact that commuter rail serves suburban areas, which traditionally are more affluent.





AUTOMOBILE OWNERSHIP
HOUSEHOLD MEDIAN INCOME

FIGURE 3-4

Table 3-4 summarizes the occupations of the respondents to the CRIP surveys. Clerical and professional employment categories account for the bulk of commuter rail users. 62.5 percent of Northside riders and 71.7 percent of Southside riders fall into one of these categories.

Professionals dominate this group. They constitute 45.6 percent of the Northside and 50.0 percent of the Southside ridership. By contrast, few (less than five percent on either service) riders are shop/factory workers or skilled tradesmen. These findings are reasonable given the dominance of white-collar industries in downtown Boston. The only noteworthy difference between the North and Southsides is the higher percentage of students--14.6 percent versus 8.5 percent on the Southside, which is consistent with trip purpose presented previously in Table 3-3A.

3.3.4 Origin and Destination Characteristics

Table 3-6 shows the community of origin of morning peak inbound trips on commuter rail. The top three communities on the Northside--Beverly (9.6 percent), Reading (7.7 percent and Wakefield (6.9 percent)--account for almost 25 percent of all Northside riders. The top eight communities (additionally, Winchester, Melrose, Lowell, Concord and Woburn) include over half of the ridership.

The distribution of Southside inbound passengers follows a similar pattern. The top three communities--Needham (11.4 percent, Norwood (6.8 percent) and Canton (6.7 percent)--account for approximately 25 percent of the total Southside ridership. Again, the top eight communities (the previous three plus Sharon, Dedham, Wellesley, Stoughton and West Roxbury) include over 50 percent of the users.

Table 3-5 shows the distribution of in-town destinations of commuter rail users. As Table 3-5 illustrates, the single largest destination of commuter rail users on both services was the Financial/Retail district. Forty-three percent of the Southside riders and 33 percent of the Northside patrons were bound for this area. Noteworthy differences between the survey responses appear to be a function of the intown terminals served--South Station and Back Bay on the Southside service and North Station on the Northside service. Noticeably higher percentages of the Northside riders were destined for the North End (eight percent) and the Government Center area (18 percent), due to their easy walking distance from North Station. Much lower percentages of Southside users had these destinations (0.8 percent and 9.9 percent, respectively). Likewise, many Southside respondents tended to have destinations in the South Station and Prudential/Back Bay areas (8.4 and 22 percent, respectively). Responses for these categories were 3.4 and 11 percent in the Northside survey.

OCCUPATION	NORTHSIDE	SOUTHSIDE
Professional	49.6%	46.4%
Clerical	20.7%	17.1%
Student	9.9%	16.5%
Sales	3.9%	2.9%
Craftsman/Foreman	3.3%	2.5%
Housewife	1.2%	2.0%
Shop/Factory Worker	1.0%	1.5%
Retired	1.0%	1.3%
Service/Domestic	0.7%	1.0%
Unemployed	0.4%	0.1%
Other	8.3%	8.7%
Total	100.0%	100.0%

AREA	NORTHSIDE (1976)	SOUTHSIDE (1976)
Back Bay	4.5%	7.5%
Beacon Hill	5.0%	1.2%
Financial/Retail	33.5%	43.3%
Government Center	18.1%	9.9%
North End	8.0%	0.8%
Park Square	2.2%	2.8%
Prudential	6.3%	14.6%
South End	2.8%	3.9%
Fenway-Parker Hill	3.6%	2.5%
Copley Square	--	--
South Station	3.4%	8.4%
Cambridge	4.4%	1.6%
Other	8.2%	3.5%
Total	100.0%	100.0%

OCCUPATION	TABLE 3-4
DESTINATIONS OF USERS (INBOUND TRIPS)	TABLE 3-5

NORTHSIDE

COMMUNITY	PASSENGERS ORIGINATING IN	PERCENTAGE OF TOTAL RIDERS	CUM. %	COMMUNITY	PASSENGERS ORIGINATING IN	PERCENTAGE OF TOTAL RIDERS	CUM. %
Beverley	717	9.6	9.6	Chelmsford	135	1.8	69.8
Reading	572	7.7	17.3	Lincoln	120	1.6	71.4
Wakefield	510	6.9	24.2	Marblehead	120	1.6	73.0
Winchester	486	6.5	30.7	Swampscott	113	1.5	74.5
Melrose	454	6.1	36.8	Hamilton	111	1.5	76.0
Lowell	442	5.9	42.7	Manchester	109	1.5	77.5
Concord	391	5.3	48.0	North Reading	109	1.5	79.0
Woburn	311	4.2	52.2	Danvers	97	1.3	80.3
Salem	209	2.8	55.0	Tewksbury	89	1.2	81.5
Acton	199	2.7	57.7	Rockport	80	1.1	82.6
Waltham	170	2.3	60.0	Lynn	75	1.0	83.6
Ipswich	165	2.2	62.2	Burlington	72	1.0	84.6
Gloucester	161	2.2	64.4	Stoneham	71	1.0	85.6
Wilmington	136	1.8	66.2	All Others	1078	14.5	100.0
Billerica	136	1.8	68.0				

SOUTHSIDE *

COMMUNITY	PASSENGERS ORIGINATING IN	PERCENTAGE OF TOTAL RIDERS	CUM. %	COMMUNITY	PASSENGERS ORIGINATING IN	PERCENTAGE OF TOTAL RIDERS	CUM. %
Needham	687	11.4	11.4	Hyde Park	168	2.8	73.1
Norwood	412	6.8	18.2	Walpole	167	2.8	75.9
Canton	406	6.7	24.9	Franklin	143	2.4	78.3
Sharon	386	6.4	31.3	Newton	122	2.0	80.3
Dedham	335	5.5	36.8	Brockton	116	1.9	82.2
Wellesley	323	5.3	42.1	Easton	105	1.7	83.9
Stoughton	321	5.3	47.4	Norton	101	1.7	85.6
W. Roxbury	312	5.2	52.6	Natick	91	1.5	87.1
Attleboro	241	4.0	56.6	Dover	81	1.3	88.4
Mansfield	235	3.9	60.5	Weston	68	1.1	89.5
Westwood	208	3.4	63.9	Framingham	66	1.1	90.6
Roslindale	194	3.2	67.1	Medfield	59	1.0	91.6
Foxborough	194	3.2	70.3	All Others	508	8.4	100.0

* Does not include boardings at Providence or Pawtucket in Rhode Island

BOARDINGS BY COMMUNITY OF ORIGIN

TABLE 3-6

Most of the destinations of commuter rail users are in Downtown Boston or Back Bay, as can be seen from Table 3-5. The percentages of users bound for Cambridge and other destinations is small (5.1 percent on the Southside and 12.6 percent on the Northside). The Eastern Route and the Fitchburg Line are the only lines that have any measurable number of destinations not in Boston or Cambridge. These destinations are in Waltham, and various places in Lynn, Salem and Beverly, the only cities existing at intermediate locations along the rail lines.

3.4 MARKET CAPTURE, 1963 and 1976

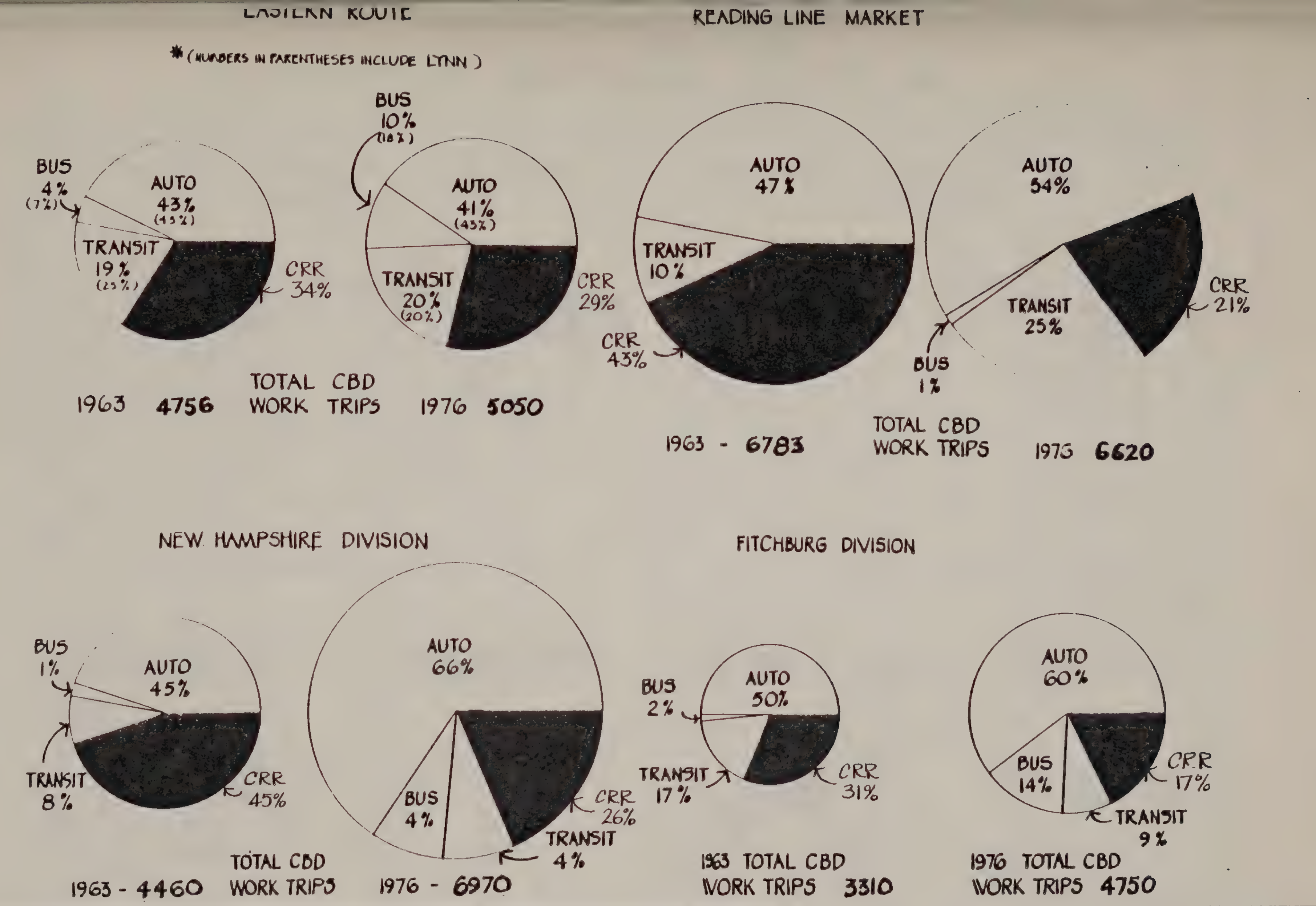
3.4.1 Overview

This section of the report describes the ability of commuter rail to "capture" trip-makers from its service area. In other words, for each town in the service area of each commuter rail line, what percentage of the trip-makers that might take commuter rail actually make that choice? Because of the nature of the data available and the fact that most commuter rail trips are work trips, this analysis is done for work trips only.

Because of the availability of extensive 1963 mode split data for all communities in Eastern Massachusetts, 1963 data was used (very little data is available for 1966). The share of work trips -- which account for the vast majority of commuter rail trips (as discussed earlier) -- captured by commuter rail as well as other modes are discussed below on a line-by-line basis (also see Table 3-4 and Figures 3-5 and 3-6). It should be noted also that the City of Newton was omitted when describing the Framingham Line market area because the 1976 rapid transit mode split was not available.

3.4.2 Eastern Route

Total work trips to Downtown Boston from communities served by the Eastern Route increased by 12 percent between 1963 and 1976. However, the share of total work trips captured by commuter rail decreased by eight percent during the same period. It appears that a majority of these trips were lost to the bus (mode split went from seven percent to 18 percent). The auto mode split remained the same and the rapid transit mode split decreased slightly.



MARKET CAPTURE, NORTHSIDE LINES
1963 & 1976

FIGURE 3-5

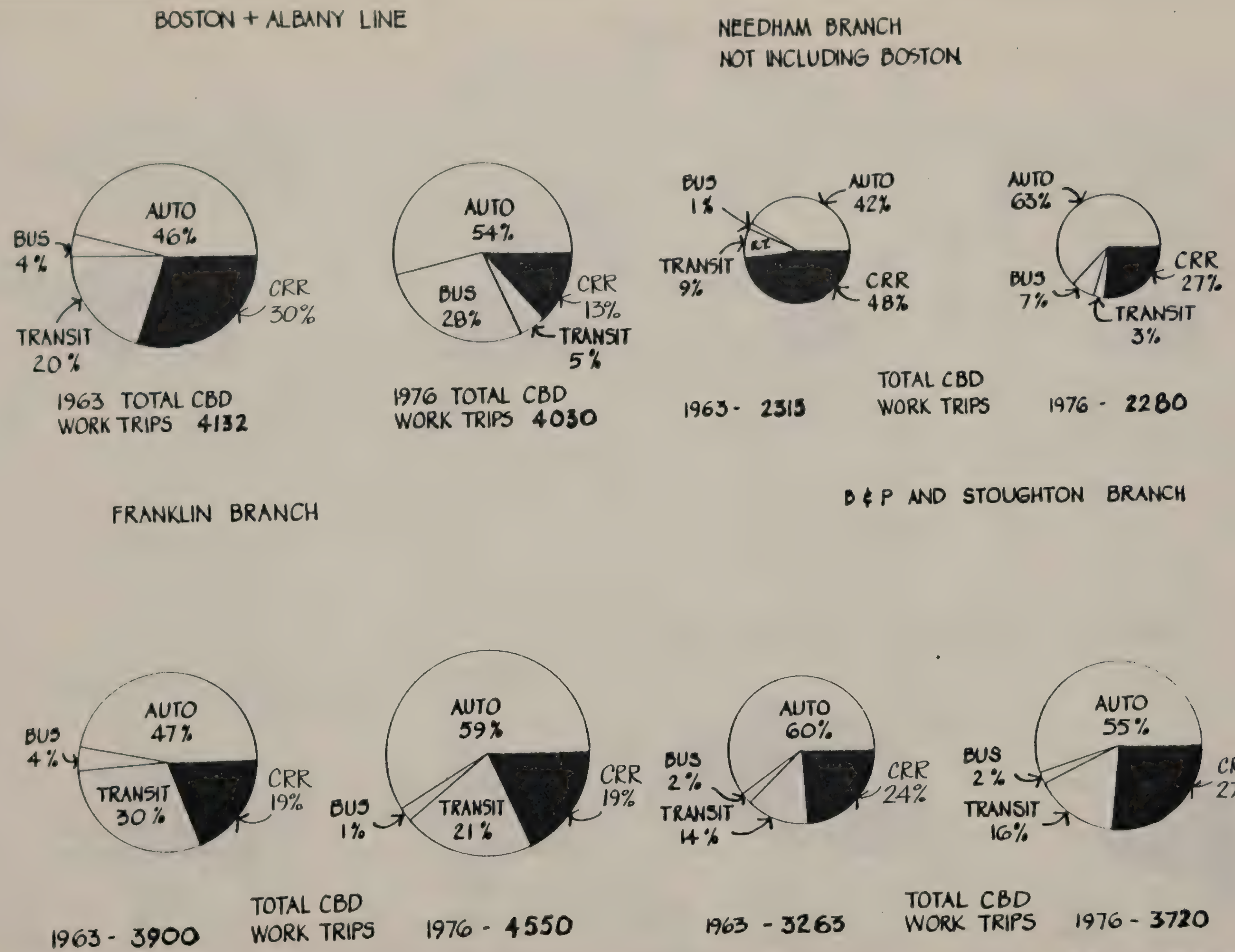


FIGURE 3-6

MARKET CAPTURE, SOUTHSIDE LINES
1963 & 1976

3.4.3 Reading Line

Total work trips to Downtown Boston from the communities served by the Reading Line decreased by two percent between 1963 and 1976. However, the share of work trips captured by rail decreased by 22 percent. It seems very likely that a majority of the trips that were lost by rail were captured by the Orange Line extension, since the rapid transit mode split increased by 15 percent during this period. The auto mode split also increased by seven percent -- this was probably due to the opening of I-93.

3.4.4 New Hampshire Division

Total work trips to Downtown Boston from communities served by the New Hampshire Division increased by 56 percent between 1963 and 1976. However, the percentage of work trips made by commuter rail decreased by 27 percent during this period. It should be noted that rail ridership increased in several communities along the route, but these increases were less than proportional to the increase in total work trips. It appears that the trips that were lost by commuter rail were lost mostly to auto, whose mode split increased by 21 percent (again, the impact of I-93). The share of work trips captured by bus increased by three percent.

3.4.5 Fitchburg Line

Total work trips to Downtown Boston from communities served by the Fitchburg Line increased by 44 percent between 1963 and 1976. However, the percentage of these trips made by rail decreased by 13 percent during this period. This loss is due to two factors: (1) the fact that new commuters to downtown from Waltham chose modes other than commuter rail, and (2) the loss of commuter rail riders from the Town of Weston (service to Weston was discontinued between 1963 and 1976).

This decline in the commuter rail mode split is partly attributable to a decrease in the level of service offered (see section on operating characteristics). Five trains arrived in Boston during the morning peak period in both 1963 and 1976. Six trains left Boston during the 1963 evening peak and four left during the 1976 evening peak. The change in actual travel time, however, is probably more significant than the actual number of trains provided. In 1963 the average scheduled travel time was 40 minutes inbound and 39 minutes outbound. By 1976 these times had deteriorated to 51 minutes inbound and 57 minutes outbound.

3.4.6 Framingham Line

Total work trips to Downtown Boston from communities served by the Framingham Line did not change appreciably between 1963 and 1976. However, the share of these trips captured by commuter rail decreased by 13 percent during this period. Therefore, in 1976, commuter rail was carrying only five percent of total downtown-oriented work trips. The level of service had declined somewhat (there were two fewer trains during the evening peak and the average scheduled travel time had increased by ten minutes). However, buses -- MBTA express buses, Gray Line and Wellesley Fells buses -- seem to be the major reason for the decline of this route. During this time the Massachusetts Turnpike Extension was opened, which provided a path for these buses, as well as attracting more commuters to their cars.

The share of work trips made by bus increased astronomically in almost every community served by this route. In 1963, only five percent of work trips from Framingham were made by bus, but in 1976 approximately 43 percent of work trips were made by bus. Comparable numbers in Natick were five percent and 23 percent. In Wellesley they were two percent and 22 percent. Auto mode splits also increased during this period, but not as much as bus mode splits.

Data on the mode splits to Newton are left out of this analysis due to the inavailability of rapid transit mode split data for 1976.

3.4.7 Needham Branch

Total work trips to Downtown Boston from non-Boston communities served by the Needham Branch remained virtually the same (decreased by 1.5 percent) between 1963 and 1976. However, the share of such trips made by commuter rail decreased sharply during this period. In 1963 almost half (45 percent) of the Downtown Boston oriented work trips from these communities were made by rail, but in 1976 the rail split had fallen to less than a third (27 percent). The absolute number of work trips made by rail from the Town of Needham (which produced over 80 percent of the work trips from the non-Boston communities served by this branch in both 1963 and 1976) decreased by almost 50 percent between 1963 and 1976, whereas total work trips decreased by only two percent. From all available data, it appears that the majority of these trips were lost to the auto. Needham's auto mode split increased by 16 percent. This is again due to the opening of the Massachusetts Turnpike Extension.

Data on the mode splits to neighborhoods in Boston are not included in this analysis due to the difficulty of disaggregating some of the data by neighborhood.

3.4.8 Franklin Branch

Total work trips to Downtown Boston from communities served by the Franklin Branch increased by 17 percent between 1963 and 1976. However, the share of work trips captured by commuter rail remained relatively stable. Hence, commuter rail ridership increased (as was shown earlier). This seeming stability reflects the fact that mode splits for rail from the smaller, more distant communities increased a great deal during this period (as much as 36 percent). It does not reflect commuter rail's seeming inability to keep existing trips or to capture new trips from the three close-in communities--Dedham, Norwood and Westwood--that account for the majority of trips on this branch. Commuter rail mode splits from these communities decreased from 34 to ten percent, 40 to 25 percent, and ten to nine percent, respectively. It appears that losses from these towns can be attributed to the bus and the auto where mode splits increased by as much as 12 percent and 31 percent, respectively.

3.4.9 Shore Line

Total work trips to Boston from communities served by the Shore Line increased by 14 percent between 1963 and 1976, and from all available data it appears that commuter rail has captured a large proportion of these trips, with only minor increases in service. The rapid transit mode split was the only other mode split that increased during this period (two percent). The auto mode split decreased by five percent.

3.5 PHYSICAL DESCRIPTION

3.5.1 Summary

This section describes the physical characteristics of the commuter rail system -- the lines themselves, the stations, the maintenance facilities and the rolling stock.

At the present time, there are eleven lines and branches, with a total of 379.3 miles of track (201.8 road miles) and 77 stations. Maintenance activities are performed in four different locations. The presently operated rolling stock includes 25 locomotives, 112 coaches and 92 Budd cars (self-propelled "RDC's").

3.5.2 Lines

A physical inventory of all MBTA commuter rail lines is presented in Table 3-7. It presents information regarding route mileage, trackage, amount and type of signaled track, line gradient and curvature, as well as an inventory of grade crossings, overhead bridges and track bridges. The Shore Line on the Southside service is the largest line by all of the quantitative criteria in Table 3-7. It has the largest number of route miles, track miles and miles of signaled track. It is the only line with more than two tracks in any location. The Shore Line also exhibits the best performance characteristics of all the lines -- minimal grade, minimal curvature and only one grade crossing. It is the only line where service can be operated at the maximum 79 mph.

3.5.3 Stations

Table 3-8 presents a summary of the conditions at the suburban commuter stations. The inventory of conditions includes platform, structures, parking and lighting. All of the Southside stations have some platform, while 89 percent of the Northside stations have platforms. On the Southside, 88 percent of the stations inspected had some form of structure at the station; the corresponding figure for the Northside was 64 percent. In the inventory of available parking, 79 percent of the Southside stations inspected and 73 percent of the Northside stations inspected had parking available. Finally, 51 percent and 41 percent of the stations inspected had more than a minimal amount of station lighting on the Southside and Northside, respectively. These simple categorizations provide a good overview of the basic "amenities" (or lack of same) available at each station. They do not attest to the generally shabby conditions of these facilities in most locations.

3.5.4 Maintenance Facilities

On the Northside service, routine maintenance, fueling and sanding of equipment is done at the Boston Engine Terminal,* just north of North Station. Heavy repair work is sent to the Billerica Back Shop.

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*Built in 1890.

	Road Miles	Track Miles	No. of Tracks	Miles of Signaled Track	Type of Signal[1]	Maximum Grade	Maximum Curve	No. of Crossings	No. of Overhead Bridges	No. of Track Bridges	Maximum Line Speed
NORTHSIDE											
Eastern Route	27.8	49.3	2/1*	47.8	1/2	1.00	5.2	26	29	25	60
Gloucester Branch	16.6	28.6	2/1	29.5	1/2	1.09	8.3	22	7	9	30
Reading Line	12.0	18.1	2/1	18.1	3	3.00	2.4	14	12	10	50
New Hampshire Line	25.4	50.8	2	62.9	3	.90	7.0	4	47	23	50
Woburn Branch	2.0	2.0	1	1.9	2	1.05%	8.0	4	1	1	25
Fitchburg Line	25.1	49.7	2	50.2	3	.79	4.3	21	26	10	40
SOUTHSIDE											
Framingham Branch	21.5	43.0	2	43.0	3	.93	5.4	2	63	10	50
Needham Branch	10.7	10.7	1	0.0	4	1.10	9.3	5	7	9	30
Franklin Branch	18.5	24.4	2/1	10.6	1	.92	4.3	7	14	26	50
Shore Line	38.2	98.2	4/2	82.3	1	.71	10.3	1	55	43	79
Stoughton Branch	4.0	4.0	1	0.0	4	.91	9.0	11	2	10	40

*No. of tracks on inner portion of line/No. of tracks on outer portion of line

[1]Type of signal: 1 - Auto block; 2 - CTC; 3 - Auto block CTC; 4 - Unsignaled.

TABLE 3-7

PHYSICAL INVENTORY OF COMMUTER RAIL LINES

Source: MBTA Rail Department

	No. of Stations	Platforms at Stations			Shelters at Stations			Parking at Stations[1]					Lighting at Stations		
								Paved		Gravel		None			
		paved	other	none	depot	other	none	lots	total spaces	lots	total spaces	none	good	poor	none
NORTHSIDE															
Eastern	15	14	1	0	1	12	2	9	1129	4	289	2	15	0	0
Reading	6	6	0	0	0	6	0	6	474	0	0	0	6	0	0
New Hampshire[2]	10	5	2	0	1	7	1	6	778	1	85	2	8	0	1
Fitchburg	14	9	3	2	0	8	6	7	536	2	88	5	9	1	4
SOUTHSIDE															
Framingham	9	9	0	0	1	7	1	5	379	0	0	4	8	0	1
Needham	8	8	1	0	1	7	0	7	580	1	230	0	5	2	1
Franklin	9	8	1	0	3	5	1	7	529	3	132	0	8	0	1
Shore Line	9	7	1	1	4	3	2	6	1500	2	160	1	8	0	1
Stoughton	2	1	0	1	1	0	1	1	100	0	0	1	2	0	0

[1] Includes municipal parking.
If a station has both paved and gravel, predominant type is noted.

[2] No information on Tufts Station.

TABLE 3-8

INVENTORY OF COMMUTER RAIL STATIONS

On the Southside, no adequate maintenance facility is available. Hence, locomotives are fueled and sanded from trucks at South Station or at the Providence Engine House. The Boston and Maine Corporation, the present operator, has a maintenance crew located at Providence for routine maintenance. Heavier work on Southside equipment is sent either to the Boston Engine Terminal or the Billerica Back Shop by crossing over to the Northside via the Grand Junction Branch.

3.5.5 Equipment

The present and expected future status of the MBTA's commuter rail equipment is shown in Table 3-9. The MBTA presently has 25 locomotives, 112 coaches and 92 RDC's on hand, although four of the locomotives and eight of the coaches are not MBTA-owned. Twenty-one locomotives, 75 coaches and 79 RDC's are needed to serve the present schedule, but, due to the age and present condition of the equipment, only 18 locomotives, 70 coaches and 72 RDC's are available on an average weekday.

Much of the MBTA's rolling stock is old, and it is expected that 17 of the locomotives, none of the coaches and 25 of the RDC's will be useable and remain in service for a period of years. However, eventually this equipment too will have to be replaced, as the MBTA develops a long-term equipment procurement plan.

3.6 SERVICE CHARACTERISTICS

On the Northside, the most frequent service is provided on the inner portions of the Eastern Line and the Reading Line, in the range of 60 to 70 trains per day, depending on the station. The shortest peak period headways are also provided on the inner portions of the Eastern Line and on the Reading Line, where the typical headways during the peak are 20 minutes. The shortest line is the Reading, whose terminal is 12 miles, or 30 minutes travel time, from Boston. The longest route is the service to Rockport via the Eastern Line and the Gloucester Branch. It takes 79 minutes to travel the 35-mile distance from North Station. Table 4-1 in the following chapter compares the present service characteristics with the characteristics of each of the alternatives analyzed in this study.

On the Southside, the most frequent service is provided at Route 128 and Canton Junction Stations, with 31 and 29 trains per day, respectively. These stations have more frequent service than other stations because both Stoughton- and Providence-bound trains stop there. The line with the most frequent overall service is the Needham

	Present Status (Jan.1978)							Future Disposition					
	Useable	Scrapped	Stored	Being Refurbed	Total on Property	Schedule Requirement	Avg.-Day Availability	Refurbished	Rehabbed	Old, but Useable	Converted to Coaches	Returned to Owner	Scrapped
Locomotives					25								
MBTA-owned	17	4[1]	-	-		21	18	-	17	-	-	-	4
D&H-owned	4	-	-	-		-	-	-	-	-	-	4	-
Coaches					112								
MBTA-owned	71	6	18	9		75	70	16	-	25	-	-	63
R.I.-owned	8	-	-	-		-	-	-	-	-	-	8	-
RDC's					92								
"Power RDC's," Northside	49	-	-	-		79	71	-	-	-	50	-	42
"Power RDC's," baggage compartment, Northside	17	-	-	-		-	-	-	-	-	-	-	-
"Dummies"	21	-	-	-		-	-	-	-	-	-	-	-
"Power RDC's," Southside	5	-	-	-		-	-	-	-	-	-	-	-

[1] Two of these locomotives are scrapped but could be pressed into service if necessary.

TABLE 3-9

MBTA COMMUTER RAIL EQUIPMENT STATUS

Branch, with all stations having 24 to 26 trains per day. The shortest peak period headways are likewise at Route 128 and Canton Junction, both 24 minutes, most of the Needham Branch stations have 30-minute headways. The longest Southside route is the Shore Line, Attleboro, the last stop in Massachusetts, is 32 miles from Boston. Due to high speeds on the Shore Line, however, it is not the longest trip in terms of time. Franklin, 28 miles away, takes an average of 61 minutes travel time during peak periods. Funds from the CRIP I Capital Grant have been spent on this branch, and soon travel times should drop to 50 minutes. Needham Heights is the closest terminal to Boston in travel time. Stoughton, 19 miles from Boston, is a 34-minute average trip in the peak period.

Scheduled speeds and frequencies do not tell the whole story about the present level of commuter rail service in the Boston region. Reliability, or the lack thereof, is another important factor which reflects on the quality of service offered. At the present time, reliability is very low. A large number of trains arrive late at their destination, and at times trains are cancelled due to equipment failure. A detailed survey of reliability was performed mid-way through the study. It showed that in some weeks as many as 35 percent of all scheduled trains are late and one to two percent are cancelled. Reliability is worse on the Southside, with 17 to 35 percent of trains late during four sample weeks in 1976. On the Northside, reliability statistics showed eight to 15 percent of trains late in the same sample weeks. As new equipment which is presently on order arrives reliability should begin to improve, but service cannot be "guaranteed" until most of the equipment in service is new or rebuilt.

3.7 COSTS

The estimated gross cost in 1977 of operating the present commuter rail system is $34,472,000 ($21,305,000 on the Northside and $13,167,000 on the Southside). These costs fall into three categories: fixed, variable and overhead. Twelve percent, or $4,298,000, of these costs are fixed costs--costs that would have to be paid even if only one line were operated on the Northside and one on the Southside. These costs include rental fees and utilities for North and South Stations, salaries for switchtenders, towermen and information clerks in the terminal areas, and maintenance of track and signals in the terminal and repair shop areas.

The costs that fall into the second category--variable costs--are costs that are directly attributable to the operation of specific lines. They represent 80 percent ($27,578,000) of total gross operating costs and include operating and non-operating labor, material and supplies, passenger incentives and fuel costs. It should be noted, however, that a small percentage of these costs are fixed costs for each line. In other words, they are incurred only due to service on an individual line, but they do not change with the amount of service on that line.

The final category of costs, overhead, represents about eight percent of total gross costs. It includes management fees, departmental costs (i.e., law, finance, personnel), and portions of the salaries of the vice presidents of the Transportation, Engineering and Mechanical Departments.

The Northside gross operating costs can be categorized as follows: Transportation Department (the costs of operating the trains)--$8,808,000; Mechanical Department (the costs of maintenance of equipment)--$6,786,000; Engineering Department (the costs of maintenance of way)--$3,705,000; all other departments (accounting, purchasing, etc.), passenger incentives and insurance--$2,006,000. The Southside costs are: Transportation Department--$6,233,000; Mechanical Department--$4,559,000; Engineering Department--$864,000; all other departments, passenger incentives and insurance--$1,511,000.

It can be seen from the foregoing that Mechanical Department costs are 33 percent higher on the Northside than on the Southside. However, Southside service is assigned 21 percent more vehicles than Northside service. This inconsistency can be explained by the types of vehicles used to provide service. Budd cars, which are quite expensive to maintain ($79,000/car), are the only type of equipment operated on the Northside,* whereas locomotives, coaches and a small number of Budd cars are used on the Southside. Locomotives are slightly more costly to maintain than Budd cars, but they account for less than a quarter of Southside vehicles. Maintenance costs for coaches, which account for a majority of Southside vehicles, are only $18,000/car.

*Except during emergency conditions when leased freight locomotives are used to pull the Budd cars.

3.8 DEFICIT ASSESSED TO CITIES AND TOWNS

As described in Section 5.2, the deficit for operating the commuter rail system is based on a number of factors. Table 3-10 presents the estimated 1977 deficit attributable to commuter rail service as it would be assessed to each of the 79 cities and towns. The total would be $10.26 million. As can be seen in this table, by far the largest portion of the deficit will be assessed to the City of Boston ($4.287 million), primarily due to the large number of express service boardings which include rapid transit. The next largest commuter rail assessments for communities with commuter rail service would be Newton's $283 thousand, Lynn's $144 thousand, Framingham's $135 thousand and Waltham's $112 thousand.

3.9 PRESENT LEVEL OF FREIGHT SERVICE

The MBTA presently owns the majority of main and branch line rights-of-way in the Boston region. On lines where commuter rail service is operated, the MBTA assumes the cost of maintenance-of-way. This fact has important consequences for the movement of rail freight in the region. The amount of freight carried on MBTA-owned lines on the Northside of Boston is summarized in Table 3-11.

Lines carrying commuter rail service require a higher level of maintenance than that needed to support freight service. The MBTA pays for this higher level of maintenance and although they receive reimbursement for the movement of freight over these lines, it does not cover total maintenance-of-way costs. Thus, B&M and ConRail are able to operate freight service over better maintained lines and at a much lower cost. In fact, for the B&M it is doubtful whether current levels of freight shipments justify the expense of maintaining the rights-of-way. Since the MBTA assumes the cost of maintenance, shippers along these lines have rail freight service which they might not otherwise have. Maintenance of way also provides a much needed positive impact on shipper's confidence. Observing that maintenance is being completed reaffirms the fact that rail service will be continued.

Community	Assessment	Community	Assessment	Community	Assessment
Arlington	174	Lynn	144	Rockland	37
Ashland	25	Lynnfield	30	Salem	81
Bedford	29	Malden	142	Saugus	69
Belmont	87	Manchester	12	Scituate	39
Beverly	89	Marblehead	55	Sharon	38
Boston	4,287	Marshfield	36	Sherborn	9
Braintree	85	Maynard	24	Somerville	266
Brookline	249	Medfield	22	Stoneham	60
Burlington	53	Medford	185	Sudbury	34
Cambridge	485	Melrose	97	Swampscott	41
Canton	42	Middleton	22	Topsfield	13
Chelsea	71	Millis	14	Wakefield	69
Cohasset	16	Milton	84	Walpole	44
Concord	35	Nahant	13	Waltham	112
Danvers	61	Natick	73	Watertown	114
Dedham	74	Needham	77	Wayland	36
Dover	12	Newton	283	Wellesley	64
Duxbury	16	Norfolk	10	Wenham	10
Everett	118	No. Reading	34	Weston	28
Framingham	135	Norwell	22	Westwood	38
Hamilton	19	Norwood	79	Weymouth	153
Hanover	25	Peabody	120	Wilmington	41
Hingham	42	Pembroke	31	Winchester	62
Holbrook	34	Quincy	328	Winthrop	61
Hull	24	Randolph	76	Woburn	95
Lexington	83	Reading	68		
Lincoln	24	Revere	171	TOTAL	10,257

TABLE 3-10

ESTIMATED 1977 COMMUTER RAIL ASSESSMENTS
BY COMMUNITY
($ THOUSANDS)

The maintenance-of-way costs borne by the MBTA have much greater implications for B&M's freight service than for ConRail's. B&M is much smaller than ConRail and presently is analyzing the viability of many of the lines in the Boston region. On the basis of monthly reports of carloads handled, it appears that B&M has lost a considerable amount of freight business in the Boston region over the last four years. The number of carloads handled has decreased on all but two of the B&M lines in the Boston region. Total carloads on the Fitchburg Main Line (W. Cambridge to Ayer) have remained relatively stable from 1972 to 1976, while a 20 percent increase in carloads handled has been realized on the New Hampshire Main Line (N. Somerville to Wilmington). Total carloads handled on other lines in the Boston region have decreased from 30 percent to 60 percent in the same time period. Therefore, the existence of the commuter rail system enables the B&M to continue freight service on many lines in the Boston region that might otherwise be abandoned.

Lines with Commuter Rail Service	1972 Number of Carloads Handled			1976 Number of Carloads Handled			%Change	1976 Avg. Number
	Received	Forwarded	Total	Received	Forwarded	Total	1972-1976	Shippers
Eastern Route Main Line (Everett-Newburyport)	6714	7440	14,154	3181	4928	8109	(43)	58
Gloucester Branch (Beverly-Rockport	359	81	440	294	8	302	(31)	6
Reading Line (Medford-Lowell Jct.)	2496	88	2584[1]	1264	359	1623[1]	(37)	11
New Hampshire Main Line (N. Somerville-Wilmington)	5049	1415	6464	6582	1165	7747	20	40
Woburn Branch (Winchester-Woburn)	294	6	300	219	0	219	(27)	6
Fitchburg Main Line (E. Cambridge-Littleton)	5624	494	6118	5497	599	6096	(.4)	33
Boston Switching Area	23754	3554	27308	12856	1873	14729	(46)	60
Other MBTA-Owned Lines	10765	2994	13659	5729	1186	6915	(49)	55

[1] Not included in totals are carloads handled in Edgeworth, Medford, and Lowell Junction.

TABLE 3-11

FREIGHT SERVICE ON MBTA RIGHTS-OF-WAY — NORTHSIDE

4.0 DESCRIPTION OF ALTERNATIVES

4.1 OVERVIEW

The four alternatives which have been analyzed are: (1) Plan A, a limited investment rail system; (2) Plan B, a stabilized rail system; (3) Plan C, a rail system with increased service levels; and (4) Commuter Bus Service. These alternatives are illustrated in Figure 4-1.

This chapter describes the alternatives, their levels of service and their requirements in terms of equipment and personnel. Table 4-1 summarizes the average service characteristics for selected stations on each line of the Northside and Southside commuter rail system. Information presented includes distance from Boston, typical peak period headway, average peak speeds to Boston and number of trains per day. In all cases, equipment requirements are consistent with estimated passenger demand.

The descriptions which follow describe the alternatives as they were designed. Certain modifications were made after the first cycle of analysis to incorporate other features, such as ensuring that enough coaches were available to carry the ridership that was forecasted. However, a key modification that was not made was the provision of expanded parking facilities in locations where projected boardings indicate the need. Nevertheless, any capital programming which results from these analyses must take this into account, since ridership will not reach projected levels if sufficient parking is not available.

4.2 PLAN A

Plan A was designed as a type of "stop gap" alternative, meant to ensure continuation of service for 5 to 8 more years, without making an irreversible commitment to continuation of commuter rail service. This alternative was necessitated by the likelihood that limited capital would be available. It was assumed that $25-40 million would be available for commuter rail.

Capital investment objectives of Plan A were to: 1) treat the most severely deteriorated conditions that may jeopardize the continuance of service; 2) use short life projects to buy time and spread available money around; and 3) to emphasize equipment, while avoiding improvements "in the ground".

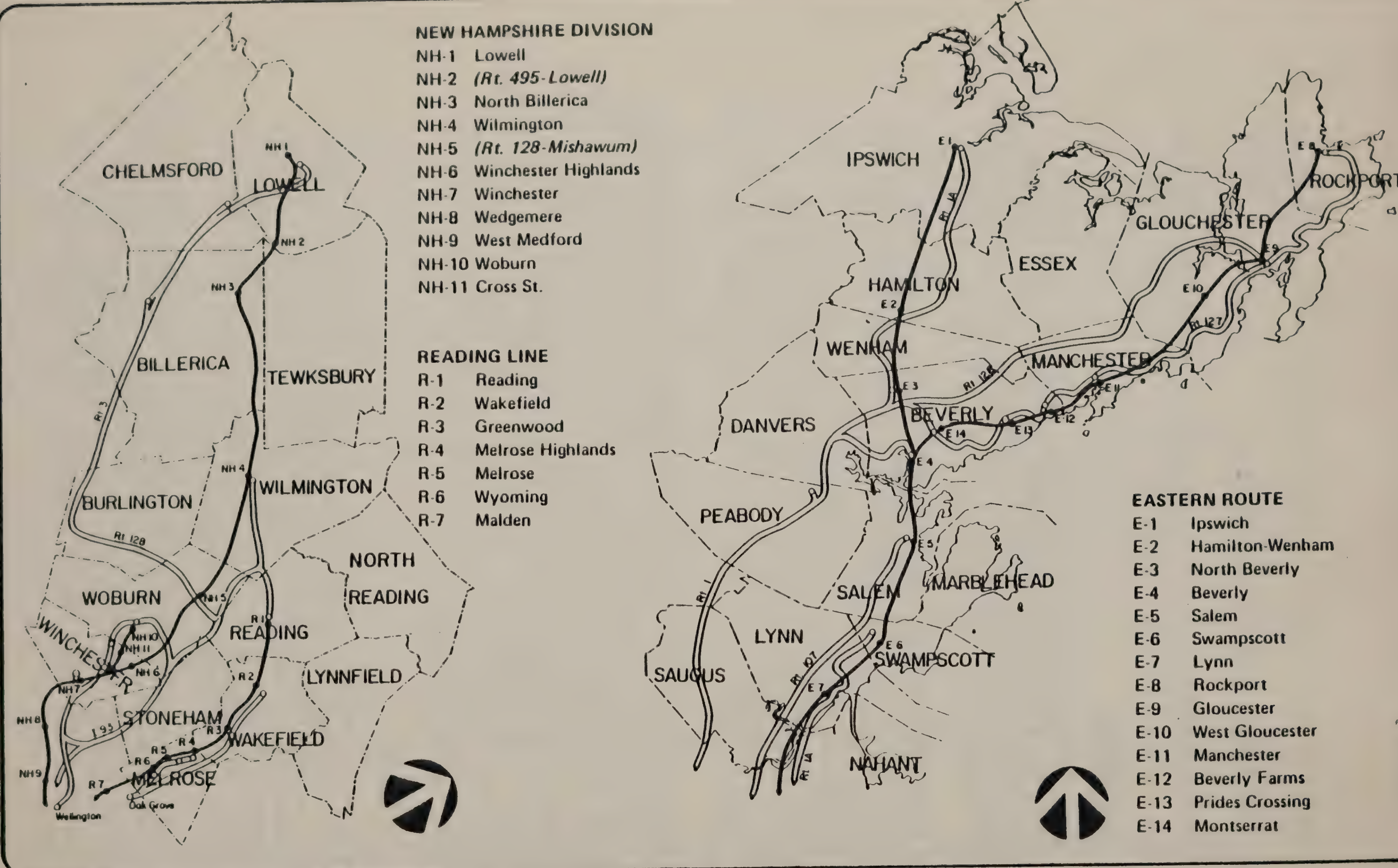
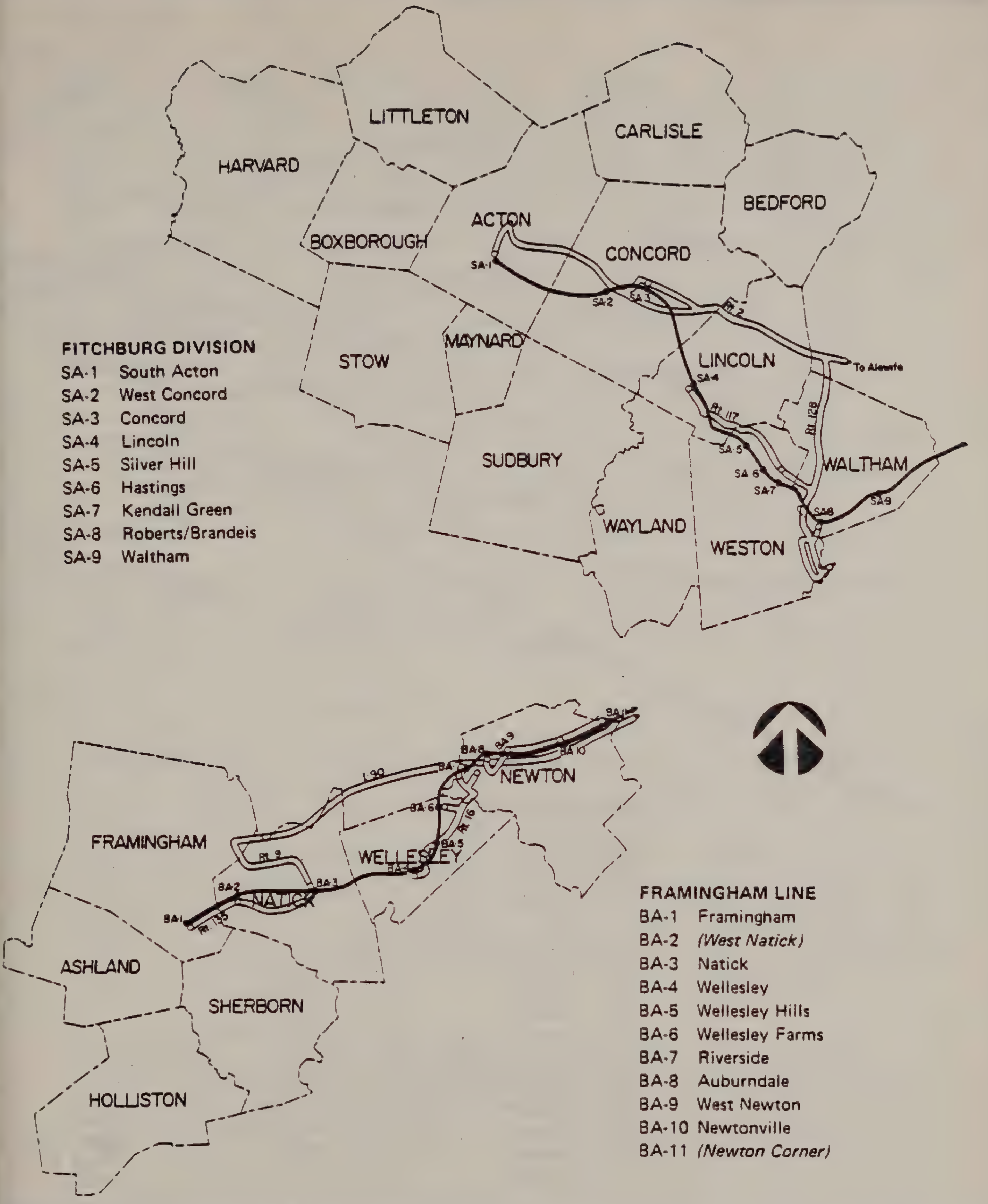


FIGURE 4-1A

RAIL LINES AND BUS ALTERNATIVES

EASTERN, READING AND NEW HAMPSHIRE CORRIDORS

SCALE: 1" = 4.1 mi.

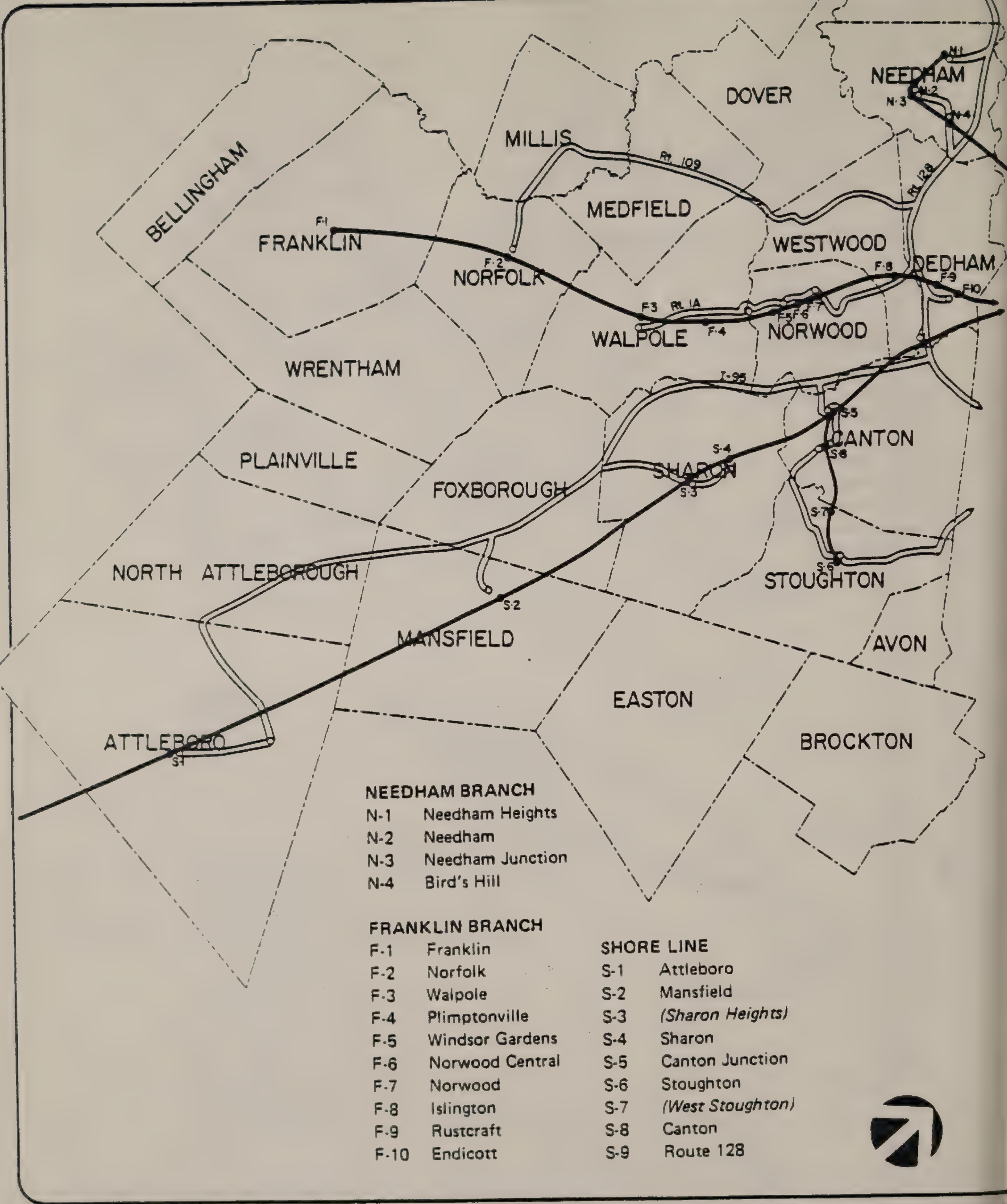


RAIL LINES AND BUS ALTERNATIVES

FITCHBURG AND FRAMINGHAM CORRIDORS

FIGURE 4-1B

SCALE:
1" = 4.1 mi.



RAIL LINES AND BUS ALTERNATIVES
NEEDHAM, FRANKLIN AND SHORE LINE CORRIDORS

Figure 4-1(

SCALE:
1" = 4.1 mi

This alternative represents almost the same level of service as that provided by the existing commuter rail system. Those changes made are the result of improvements expected due to increased reliance on locomotives instead of Budd Cars (self-propelled diesel cars). Other changes are the result of minor operational changes or schedule modifications.

Frequency of service ranges from 20 to 25 minutes on the Reading Branch, the Eastern Route to Beverly, the New Hampshire Route to Woburn and the Framingham Line. Headways on all other lines average from 40 to 45 minutes. Average speeds range from 20 to nearly 40 mph. The highest average speeds of 35 to 40 mph occur on the Shore Line and the lowest speeds of 20 to 25 mph are found on the Framingham Line. The low speeds on the Framingham Line are a result of all trains running as locals. Compared to the present system, only Fitchburg shows any improvement in running time (five minutes). Reliability is increased due to locomotive-hauled service. Average lateness* is decreased 80% on the Northside and 65% on the Southside.

Plan A would require 196 operating personnel composed of 64 engineers, 62 conductors and 70 trainmen. Equipment needed for this service would include 40 locomotives, 23 RDC's and 136 coaches.

4.3 PLAN B

The level of investment specified under Plan A could not support the continuation of rail service over an extended period of time. Therefore, a second alternative was defined which would provide for further upgrading of track and bridges plus all new or rebuilt equipment. These capital investments provide the basic level of improvements needed to continue the service offered under the existing commuter rail system, and would significantly improve service reliability. Plan B represents a definite commitment to remain in business, with an eye to the future, but without major upgrading of service frequency.

Investment in Plan B throughout the system was expected to cost $150-200 million additional dollars over the amount already committed as of March 1978. (The CRIP III grant of $25 million which has recently been approved had not been developed at that time.) The four primary capital

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* See Section 5.2.1 for a description of this measure of reliability and its impact on ridership.

	Distance to Boston (miles)	Present Commuter Rail System		Plan A		Plan B		Plan C		Commuter Bus Service	
		Avg. Speed (mph)	Freq. (min)	Avg. Speed (mph)	Freq. (min)	Avg. Speed (mph)	Freq. (min)	Avg. Speed (mph)	Freq. (min)	Avg. Speed (mph)	Freq. (min)
Northside											
Eastern Line											
Beverly	18.3	33	20	31	25	37	20	46	12	20	15
Ipswich	27.8	31	40	29	42	36	40	45	24	25	35
Rockport	35.3	28	45	27	45	31	43	41	24	24	35
Reading Line											
Melrose Hlnds.	7.5	28	20	28	20	28	20	30	15	17	10
Reading	12.0	29	20	29	20	29	20	36	15	21	10
New Hampshire Div.											
Wilmington	15.2	34	45	34	45	42	45	43	10	34	30
Lowell	24.5	34	45	34	45	42	45	45	20	35	20
Woburn	10.0	26	24	29	26	30	24	32	15	24	30
Fitchburg Line											
Waltham	9.9	25	22	28	23	32	23	40	15	-	-
Lincoln	16.7	26	22	29	23	33	23	37	15	37[4]	15
South Acton	25.1	28	22	31	23	35	23	40	15	35[4]	20
# of Weekday Trains		258[1]		230[2]		230		464			

[1] As of September 1977

[2] Reflects changes effective October 1977.

[3] Average speed with South Station as terminus

[4] Alewife station terminus

TABLE 4-1 P.1

AVERAGE SERVICE CHARACTERISTICS FOR COMMUTER RAIL ALTERNATIVES
(PEAK PERIOD)

	Distance to Boston (miles)	Present Commuter Rail System		Plan A		Plan B		Plan C		Commuter Bus Service	
		Avg. Speed (mph)	Freq. (min)	Avg. Speed (mph)	Freq. (min)	Avg. Speed (mph)	Freq. (min)	Avg. Speed (mph)	Freq. (min)	Avg. Speed (mph)	Freq. (min)
Southside											
Framingham Line											
Auburndale	10.5	23	30	24	25	26	25	31	15	20[3]	30
Wellesley Ctr.	14.5	20	30	21	25	23	25	33	15	29	30
Framingham	21.5	23	30	24	25	26	25	33	15	29	30
Needham Branch											
W. Roxbury	8.5	21	30	21	30	24	30	23	15	13	6
Needham Hts.	14.0	21	30	21	30	24	30	29	30	25	35
Franklin Branch											
Endicott	11.0	34	47	34	44	34	44	37	15	18	36
Norwood Cntrl.	15.0	28	47	28	44	31	44	41	15	24	20
Franklin	28.0	28	47	28	44	31	44	38	30	28	15
Shore Line											
Readville	10.0	27	40	27	40	27	40	27	15	33	25
Sharon	18.5	38	40	38	40	38	40	38	15	26	20
Attleboro	32.0	37	40	37	40	37	40	37	30	33	30
Stoughton Ctr.	19.0	34	42	33	42	34	42	34	15	24	20
# of Weekday Trains	40.0	80[1]		98[2]		98		266			

[1] As of September 1977

[2] Reflects changes effective October 1977.

[3] Average speed with South Station as terminus

TABLE 4-1 P.2

AVERAGE SERVICE CHARACTERISTICS FOR COMMUTER RAIL ALTERNATIVES (PEAK PERIOD)

investment objectives of Plan B were to: 1) make permanent investments to the most severely deteriorated areas that affect continuance and reliability of service; 2) reestablish a reliable base operation; 3) emphasize on-train reliability and defer off-train improvements and amenities; and 4) make improvements with long, or medium length useful life.

Plan B does not include projects for which the only justification is return on investment, or such projects as station modernization, new stations, parking areas, additional track or rights-of-way.

In relation to improvements that have been made to date, Plan B is quite similar to the work done on the Franklin Branch with two exceptions. As mentioned above, Plan B includes no station modernization although the Franklin Branch has received some. The second difference is that Plan B includes signal work, and no signal work has been done on the Franklin.

The frequency of service under this alternative is similar to that under Plan A and the existing system. However, due to the increase in power of locomotives over RDC's, running times five to ten minutes faster would exist on all but the Reading, Woburn and Shore Lines. This results in moderately increased running speeds on the Fitchburg, Franklin, Needham and Framingham routes, and significantly increased speeds on portions of the Eastern and New Hampshire lines. Service reliability would be further enhanced over the existing system with a system-wide improvement in average lateness of 93 percent.

This alternative would require the same number of operating personnel as the Plan A alternative (64 engineers, 62 conductors, 70 trainmen). Equipment needed to operate the system consists of 40 locomotives and 178 coaches. RDC's are deleted from the system due to their high operating costs and low reliability. It is expected that many of the existing RDC's can be converted to coaches.

4.4 PLAN C

The most optimistic rail alternative, Plan C was designed to significantly upgrade the commuter rail system, to provide fast, frequent and reliable service throughout. It was expected that Plan C would cost over $300 million dollars. The objectives of investing in Plan C would be: 1) to upgrade service and amenities to nearly rapid transit levels including equipment, station modernization and parking facilities; and 2) to make permanent improvements with long useful lifetimes.

The types of capital investments required would include completion of all deferred track, bridge and signal maintenance so that thereafter only routine maintenance would be required. Maintenance facilities would also be brought up to modern standards. Further, some lines and some locations would be double-tracked to enable provision of desired service levels.

The highest level of Northside service would be on the inner segments of the New Hampshire Division and Eastern Line, with peak headways of ten minutes. On all other segments of Northside lines, headways average from 15 to 20 minutes. On the Northside lines average speeds would improve over Plans A and B. Five to ten mph improvements would be made on the Fitchburg and Eastern Lines, with smaller increases on the Reading and New Hampshire Lines. The longest running time of 52 minutes would be to Rockport.

On the Southside, peak headways would be 15 minutes on the Framingham Line and inner segments of the other three lines. These headways represent significant improvements over Plans A and B (ten to fifteen minutes). The more significant improvements in average speeds would occur on the Framingham and Franklin Branches, where express or skip-stop trains would be added to the schedule. The longest running time on the Southside is 52 minutes, to Attleboro.

For this alternative, a total of 367 operating personnel would be required. This figure includes 126 engineers, 126 conductors and 115 trainmen. Equipment needed to operate the system would consist of 52 locomotives and 256 coaches.

4.5 COMMUTER BUS SERVICE

4.5.1 Design of Commuter Bus Alternatives

The fourth alternative is a bus service which replicates, as far as possible, current commuter rail service. The first step in the development of such a system was to review statistics on present commuter rail ridership by station and by time of day. Then, assuming that commuters would desire a Boston arrival and departure schedule similar to that provided by the commuter rail system, alternative bus services were designed to match that schedule. Whenever possible, express service was scheduled between suburban locations and Boston. However, in certain cases current ridership levels did not justify such service. In these situations a number of locations were combined into a single bus run.

The next step involved the selection of the fastest possible highway routes. New bus service was designed for the majority of locations served by commuter rail, but in some instances additional bus service could not be designed which surpassed the quality of service provided by local bus access to transit stops. From other locations, namely Framingham and Beverly, private carriers already provide service to Boston. Therefore, it was not necessary to schedule as much replacement service on these routes.

The final steps in designing the bus service were the compilation of runs so as to cycle the use of buses as efficiently as possible and then checking these runs against driver work rules.

Downtown destinations of the commuter bus alternatives were oriented toward matching the desires of present rail patrons with the street patterns and availability of space for station facilities in Boston. Most Northside bus services would be terminated at Haymarket Station, although some bus routes from the Fitchburg Line corridor would terminate in Cambridge and others in Post Office Square. Southside bus services would terminate in Copley Square or at South Station.

4.5.2 Line-by-Line Summary

The alternative bus services are described below. Table 4-2 summarizes the service on each line, including the number of routes operated and the number of vehicles that would be needed.

Eastern. The current analysis of bus service for the Eastern Route proposes operation of 12 bus routes. Some routes would operate during peak hours only and some during off-peak hours only. Most of these routes would approach Boston via U.S. Route 1 and the Mystic-Tobin Bridge. Although Interstate 93, to the west of Route 1, is less congested, the additional access time would cancel out this advantage under normal traffic conditions.

Reading. Alternative service along this route would consist of three bus routes. The first would serve Reading Station only, the second would serve as a feeder to Oak Grove from Wakefield and Greenwood Stations, and the third would also access Oak Grove and provide service from Melrose Highlands, Melrose and Wyoming Stations. It is assumed that all three routes will run during morning and evening peak periods only, on headways of ten to 15 minutes. During midday and at night, former rail users would have to rely on existing transit service in this corridor.

Bus Routes	Total # of* Bus Routes	Number of Required Buses	Number of Spare Buses	Total # of Buses Assigned
Eastern Route	12	39	7	46
Reading	3	18	3	21
New Hampshire	11	33	6	39
Fitchburg	9	20	4	24
Framingham	6	18	3	21
Needham	11	24	4	28
Franklin	24	30	5	35
Shore Line	25	61	11	72
TOTAL	101	243	43	286

* Includes basic routes plus their variations.

COMMUTER BUS ROUTES

TABLE 4-2

New Hampshire. Ten new bus routes plus increased service on bus route 134W is proposed as an alternative to the existing service on this line. Route I-93 provides good access to Boston from this corridor and would be used for many of the commuter bus routes.

Fitchburg. The commuter bus service designed to serve the Fitchburg corridor assumed the present public transit system. This system consisted of eight new bus routes plus increased service on one existing route. However, once Red Line service is extended to Alewife, it is more realistic to terminate most of the bus routes at this station. Therefore, a revised commuter bus service was designed to serve as a feeder to that station. This system consists of nine new bus routes plus increased service on existing route 305.

Framingham. Alternative bus service for this line would consist of six bus routes which would be operated by private carriers, by the MBTA or by a combination of the two. Each route would have one departure for each existing train, and would take advantage of the free-flowing Massachusetts Turnpike. In addition, if traffic flow increases on the Pike, there is potential for provision of a special-purpose lane to ensure maintenance of high speeds for the express buses.

Needham. The service for this route would consist of MBTA-operated express buses to Copley Square and South Station from the four Needham stations during peak hours and a shuttle bus from these same stations to the Riverside Green Line station during midday. To serve the Roslindale, Bellevue, Highland and West Roxbury Stations a short-turn bus operating on a ten-minute headway from West Roxbury to Forest Hills would be added to existing service during the AM and PM peak hours. These buses would be continued through to Copley Square if demand warranted it.

Franklin. The analysis of alternative service for the Franklin Branch proposes operation of ten new bus routes. Most of these routes would have one or more short-turn variations. The large number of routings relative to the number of stations served was necessary in order to maintain reasonable load factors while attempting to minimize travel time.

Shore Line. In designing alternative service for the Shore Line and the Stoughton Branch, it was assumed that service to points in Rhode Island was not the responsibility of the MBTA or the Commonwealth of Massachusetts. Presumably, Bonanza Bus Lines would expand service from Providence to Boston as necessary to accommodate additional demand if commuter rail service were dropped. The scheduled bus running time from Providence to Park Square is 55 minutes, which is less than the scheduled commuter rail time at present.

To replace service at stations within Massachusetts, the current analysis proposed operation of ten basic bus routes, most of which would have some variations.

From most communities in the Providence Line corridor to downtown Boston, the shortest highway distance would be via the Southeast Expressway. However, due to traffic congestion on the expressway, trip times during peak hours would be minimized by routing buses via the Massachusetts Turnpike extension. Therefore in the analysis it has been assumed that peak trips would use the Turnpike but that off-peak trips would use the expressway.

4.5.3 Level of Service

This section summarizes the level of service that would be offered in the commuter bus alternative; for a detailed description of schedules and running times refer to appendix A.3.

On the Northside, the highest peak headways of ten minutes are found on the Reading Line replacement service. The next best service, with 15-minute headways, would be to certain points receiving commuter bus service on the Fitchburg Line and the Eastern Line. The longest running time of 88 minutes will be to Rockport on the Eastern Line. Average speeds to points serving as terminals for the rail lines will be about 20 to 25 mph, with the exception of service to Lowell having an average speed of 35 mph.

The most frequent service on the Southside would be on the inner segments of the Needham Branch where the peak combined headways for Forest Hills through West Roxbury will be six minutes. (This replacement service is provided by local buses to the Orange Line.) However, peak service to the last four points on this route have only 35-minute headways. On the Framingham Line, headways are the same as existing rail service and average speeds are slightly improved. On the longest route, the Shore Line, running time to Attleboro is 58 minutes. Average speed to Attleboro is 33 mph, the fastest of any Southside bus route and comparable to the average speed of the commuter rail alternatives. Two hundred and twenty-eight buses (excluding spares) and 243 drivers would be needed to operate both the Northside and Southside bus service.

5.0 EVALUATION OF SYSTEM ALTERNATIVES

5.1 SUMMARY

This chapter presents the costs, deficit, ridership and revenues of the three rail alternatives and the commuter bus service. Further, there are descriptions of the methodology employed in determining the expected costs and ridership associated with each alternative and the composite system; and the deficit that would be assessed to each community in the MBTA district. All monetary figures are based on 1977 dollars.

The estimated total gross cost of operating the present commuter rail system is $34,472,000; the estimated gross cost of operating Plan A is $32,111,000 (seven percent savings); the estimated gross cost of operating Plan B is $30,530,000 (13 percent savings); the estimated gross cost of operating Plan C is $43,885,000 (24 percent increase). The major portion of costs for each of the three systems is variable with the level of service provided. The capital costs required to implement Plan A is $53,874,000. The capital cost required to implement Plan B is $149,167,000. The capital cost requited to implement Plan C is $330,375,000.

The total estimated gross cost of operating the commuter bus service is $18,136,000. This represents savings of $16,337,000 (47 percent) over the costs of operating the present rail system. However, it should be noted that the bus system would increase travel times significantly for some commuters. Finally, before this bus service could be operated, $31,460,000 must be spent on buses, garages, and a terminal facility.

Analysis of ridership on the four alternatives has shown that there would be an increase of 14.7 percent for the Plan A alternative system, 26 percent for the Plan B alternative system, 81 percent for the Plan C alternative system, and a decrease of 29 percent for the Commuter Bus service. The decrease in ridership on the Commuter Bus service is due in large part to the inability of the existing highway system to provide comparable line-haul times, especially along the Eastern Route and along the commuter rail lines in Boston's Southwest Corridor. Projections of total work trips to Downtown by all modes show that the greatest proportional increases in the potential rail market over 25 to 30 years are likely to occur in the areas served by the Shore Line and Fitchburg routes.

The following subsections describe the costs, ridership, and revenues associated with each alternative summarized above in more detail.

5.2 METHODOLOGY

5.2.1 Travel Forecasting

The process of forecasting travel on commuter rail required a determination of the relationship between level of service and ridership in Boston. This was necessary because no existing model of transit ridership was based on just commuter rail, and since users of commuter rail make their travel decisions in a different way than most transit riders.

The model was based on the November 1976 service and ridership patterns in the Boston area. Primarily, this data was obtained from a survey of commuter rail riders at that time. Also of importance was data on auto drivers and other transit riders. These data were obtained from numerous surveys* and 1970 Census data.

Incorporated into the model are travel time, waiting time, reliability of service, and cost (fare or auto operating cost) for each mode (auto, rail or bus); as well as, household income and travel distance. These data are then used to determine the relative importance of each characteristic, and finally to determine how many travelers in each service area choose commuter rail.

In order to estimate ridership, the level of service for each station must be determined; schedules are drawn up which show the frequency of train service, and the running times from each station to downtown. An estimate is also made of the reliability of service, based on the percent of trains expected to be on time. These level of service characteristics are then compared to levels of service in the present system and to auto speeds to estimate mode split (or the percent of travelers expected to use the service) and then the total number of riders expected to use the alternative service. Projected 24-hour inbound boardings are shown in Table 5-4 and projected annual revenues are shown in Table 5-5.

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* 1963 Home Interview Survey, 1976 Oak Grove Survey, 1976 Framingham/Natick Survey, 1977 Blue Line Survey, 1977 Roxbury Survey, numerous small express bus surveys.

Reliability is an important attribute affecting people's choice of travel mode; it is particularly important for travel to work by commuter rail. Measurement of commuter rail reliability was based on reported train delays for the year 1977 resulting in the calculation of average delay per train on each line (this average also included trains which were not late at all), and the variability of that delay (since travellers have to plan additional waiting time when the variability of delay increases). For each plan, as well as for the commuter bus alternative, improved reliability values were assumed, and then translated into a decrease in average delay. The model used showed that ridership would increase by about three percent for each 10 percent decrease in average delay.

The travel forecasting procedure used for this study is very similar to ones used in other studies, with three notable exceptions. First, the model was developed based on individual household characteristics (not just zonal characteristics). Second, the model was developed using distinct transit modes (commuter rail, express bus, and rapid transit were distinct and not treated as a "generic" transit mode). The third difference was that reliability as a measure of service was incorporated into the model. In addition, due to the different objectives of each study, the levels of service analyzed may differ somewhat as between Phase 2 of the North Shore Transit Improvements Project and the CRIP Plan Refinement Study. Service assumptions were made to be as consistent as possible* between these two studies. Even so, they did vary slightly.

After ridership for each alternative was estimated, the potential for growth in that ridership was determined. This growth potential is based on projected growth in work trips to downtown from each suburban zone, which depends in turn on projections of suburban population, downtown employment and employment elsewhere. For example, as population grows in a town served by commuter rail, and as employment grows and redistributes throughout the region, the number of trips to downtown will increase somewhat, and hence, the potential market for commuter rail will change. In most communities, the increase in the growth is relatively small, since most employment growth will continue to occur outside of downtown Boston.

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* A memo dated March 13, 1978 clarifies the differing assumptions that were used by the two studies.

As important as the growth in market potential is the change in market capture. Section 3.4 shows how market capture changed from 1963 to 1976. These capture effects were a result of changes in other transportation facilities and changes in auto ownership. It is difficult to predict whether commuter rail shares of the market after they increase because of better service, would continue to follow these mostly downward trends in the future. It could be argued that the forces behind these trends have already had their effect (I-93 and the Oak Grove rapid transit extension with regard to the Reading Branch, for example) or that highway capacity limits and rising auto costs would work in the opposite direction, to the disadvantage of competing travel modes. Therefore, no attempt has been made in this analysis to forecast the long-term ability of commuter rail or commuter bus to capture portions of an expanding market. The analysis has focused on the growth in the potential market based on anticipated growth in travel to the Boston CBD. The growth in the potential market was estimated as a function of population growth in the municipalities along each rail corridor and employment growth in the Boston CBD relative to the region.

The ridership growth potential in each corridor to the years 1985 and 2005 was analyzed for Plans B and C and the commuter bus, with results as shown in Tables 5-6 through 5-8. The different growth rates associated with the three alternatives are due to the fact that each alternative draws in different degrees from municipalities having different projected population growth. Appendix A-1 explains in more detail the process of forecasting ridership for the alternative plans.

5.2.2 Cost Analysis

Along with analysis of ridership, costs of the various alternatives were analyzed. Operating costs were based on service levels, B&M work rules, and expected savings due to improvements made to equipment and facilities. Costs from 1977 operations were used to determine the base levels. All costs are shown in 1977 dollars, in Tables 5-1, 5-2 and 5-3.

The three major components of operating costs are transportation costs (operating the trains), mechanical costs (maintaining the equipment) and engineering (maintaining the rights-of-way). Analyses included direct operating costs, fixed costs and overhead costs.

Capital costs for equipment are based on estimates made by the MBTA Commuter Rail Department and consultant estimates. Capital costs were annualized using appropriate lifetimes for each type of improvement and using a discount rate for the time value of money of 9%.

CAPITAL AND OPERATING COSTS - NORTHSIDE SYSTEM*

	PRESENT SYSTEM	PLAN A	PLAN B	PLAN C	COMMUTER BUS
Capital Cost	---	38,453	9,677	22,898	1,407
Annualized Capital Cost**	---	4,305	101,677	236,747	10,187
OPERATING COST BY DEPARTMENT					
Transportation Department					
Fixed	1,309	1,309	1,309	759	---
Variable	7,419	7,775	7,748	11,757	4,075
Allocated Overhead	80	80	80	80	---
Subtotal	8,808	9,164	9,137	12,596	4,075
Mechanical Department					
Fixed	467	467	467	467	---
Variable	6,266	2,394	2,944	4,864	2,950
Allocated Overhead	53	53	53	53	---
Subtotal	6,786	2,914	3,464	5,384	2,950
Engineering Department***					
Fixed	1,121	1,026	1,026	1,026	---
Variable	2,584	2,164	2,164	2,164	126
Allocated Overhead	---	---	---	---	---
Subtotal	3,705	3,190	3,190	3,190	126
All Other Departments					
Fixed	252	252	252	252	---
Variable	622	2,135	832	1,426	---
Allocated Overhead	1,132	896	926	1,243	1,155
Subtotal	2,006	3,283	2,010	2,921	1,155
TOTAL OPERATING COST	21,305	18,551	17,801	24,091	8,306

* All figures in $1,000's

** Capital Costs were annualized on a project by project basis according to assumed life span. These annualized costs were then aummed to get total costs for a given alternative.

*** Actual costs for this department were available by the end of the study and were used in all the alternatives.

CAPITAL AND OPERATING COSTS - NORTHSIDE SYSTEM

TABLE 5-1

CAPITAL AND OPERATING COSTS - SOUTHSIDE SYSTEM*

	PRESENT SYSTEM	PLAN A	PLAN B	PLAN C	COMMUTER BUS
Capital Costs	--	15,421	47,490	93,628	11,273
Annualized Capital Cost**	--	1,578	4,632	8,446	1,567
OPERATING COST BY DEPARTMENT					
Transportation Department					
Fixed	1,362	1,362	1,362	1,362	--
Variable	4,596	4,709	4,707	8,877	4,424
Allocated Overhead	275	275	275	275	--
Subtotal	6,233	6,346	6,344	10,514	4,424
Mechanical Department					
Fixed	363	363	363	363	--
Variable	3,983	3,924	3,101	4,296	3,695
Allocated Overhead	213	213	213	213	--
Subtotal	4,559	4,500	3,677	4,872	3,695
Engineering Department***					
Fixed	--	--	--	--	--
Variable	775	775	775	775	343
Allocated Overhead	89	89	89	89	--
Subtotal	864	864	864	864	343
All Other Departments					
Fixed	--	--	--	--	--
Variable	632	968	1,023	1,318	--
Allocated Overhead	879	883	821	1,225	1,368
Subtotal	1,511	1,851	1,844	2,543	1,368
TOTAL OPERATING COST	13,167	13,561	12,729	18,793	9,830

* All figures in $1,000's

** Capital costs were annualized on a project-by-project basis according to assumed life spans. These annualized costs were then summed to get total costs for a given alternative

*** Actual costs for this department were available by the end of the Study and were used in all the alternatives.

CAPITAL AND OPERATING COSTS - SOUTHSIDE SYSTEM

TABLE 5-2

	Present System	Plan A	Plan B	Plan C	Commuter Bus
Eastern	$ 7,551,000	$ 6,645,000	$ 6,196,000	$10,222,000	$ 3,032,000
Reading	4,400,000	4,005,000	3,654,000	4,213,000	895,000
New Hampshire	5,278,000	4,540,000	4,615,000	5,626,539	2,840,000
Fitchburg	4,076,000	3,361,000	3,336,000	4,030,000	1,539,000
Framingham	1,156,000	1,443,000	1,414,000	2,823,000	805,000
Needham	2,955,000	4,233,000	3,246,000	3,819,000	861,000
Franklin	2,226,000	2,202,000	2,294,000	3,658,000	2,386,000
Franklin	2,226,000	2,202,000	2,294,000	3,658,000	2,386,000
Shore Line	6,831,000	5,681,000	5,775,000	8,493,000	5,778,000
TOTAL	$34,473,000	$32,110,000	$30,530,000	$42,885,000	$18,136,000

TABLE 5-3

GROSS OPERATING COSTS BY LINE

	Present System	Plan A		Plan B		Plan C		Commuter Bus	
	Inbound 24-Hour Board-ings	Inbound 24-Hour Board-ings	Percent Change	Inbound 24-Hour Board-ings	Percent Change	Inbound 24-Hour Board-ings	Percent Change	Inbound 24-Hour Board-ings	Percent Change
Northside									
Eastern	2550	2620	2.7	3190	25.1	6860	170.0	1410	-44.7
Reading	2220	2340	5.4	2740	23.4	3470	56.3	1860	-16.2
New Hampshire	2140	2510	17.3	2690	25.7	3820	78.5	1250	-41.5
Fitchburg	1600	1890	18.1	1980	23.7	2340	46.2	1360	-15.0
TOTAL NORTHSIDE	8550	9360	9.5	10600	23.9	16490	93.0	5880	-30.8
Southside									
Framingham	850	1120	31.7	1190	40.0	1450	70.5	860	+ 1.1
Needham	1470	1720	17.0	1850	25.8	2270	55.0	1150	-21.7
Franklin	1265	1550	22.5	1660	31.2	2180	72.3	710	-43.8
Shore Line	3260	3810	16.8	4030	23.6	5410	65.9	2320	-28.8
TOTAL SOUTHSIDE	6845	8200	19.8	8730	27.5	11310	65.7	5040	-26.4
SYSTEM TOTAL	15345	17560	14.4	19330	25.9	27800	81.2	10920	-28.8

TABLE 5-4

PROJECTED DAILY BOARDINGS

	Present System	Plan A		Plan B		Plan C		Commuter Bus	
	Revenue	Revenue	% Change	Revenue	% Change	Revenue	% Change	Revenue	% Change
Northside									
Eastern	1.77	1.82	2.8	2.21	24.9	4.75	169.0	0.98	-44.6
Reading	1.12	1.18	5.3	1.38	23.2	1.74	55.3	0.93	-16.9
New Hampshire	1.37	1.60	16.8	1.72	25.5	2.44	78.1	0.80	-41.6
Fitchburg	1.15	1.36	18.3	1.42	23.4	1.68	46.0	0.98	-14.8
TOTAL NORTHSIDE	5.41	5.96	10.2	6.73	24.4	10.61	96.1	3.69	-31.8
Southside									
Framingham	0.40	0.53	32.5	0.56	40.0	0.69	72.5	0.41	+ 2.5
Needham	0.62	0.73	17.7	0.78	25.8	0.96	54.8	0.49	-21.0
Franklin	0.72	0.88	22.2	0.94	30.5	1.24	72.2	0.40	-44.0
Shore Line	1.72	2.01	16.9	2.13	23.8	2.85	65.7	1.22	-29.1
TOTAL SOUTHSIDE	3.46	4.15	19.9	4.41	27.5	5.74	65.8	2.52	-27.2
SYSTEM TOTAL	8.87	10.11	13.9	11.14	25.6	16.35	84.3	6.21	-25.7

TABLE 5-5

PROJECTED ANNUAL REVENUE
($ MILLIONS - 1977 DOLLARS)

5.2.3 Deficit Analysis

After costs and revenues were calculated, the total operating deficit for the system was known. This deficit would be paid for in part by Federal and state operating subsidies, and the remainder would be apportioned among the cities and towns of the MBTA district. Analyses done here have followed the present apportionment formula to determine the impact of commuter rail service on the MBTA deficit apportioned to each town. This was done both for the present system and for a "composite system", in which the least cost effective commuter rail lines would be replaced by commuter bus and, alternatively, in which a minimum investment plan (Plan A) were in place on such lines.

At the present time, a special federal subsidy program, Section 17, is used to pay for transition costs for transfer of Southside services from Penn Central to Conrail to B&M operations. Another Federal program, Section 5, pays general operating assistance, a portion of which goes toward commuter rail costs. A portion of state subsidies for the MBTA also goes toward commuter rail costs. Outside community charges (for service beyond the MBTA boundary) are also subtracted from the total deficit. Approximately 47% (in recent years) of the non-Section 17 deficits have been paid by the cities and towns. These are apportioned on the basis of number of commuters (75% of remainder) and on the basis of number of boardings (25% of remainder).

In order to determine the deficit of the composite system, it was assumed that all changes would be in place by 1985. Hence, costs and revenues had to be inflated over an eight year period. Costs were inflated based on the average inflation rate over the past eight years, and revenues were inflated based on the average fare increase over that period. Section 17 assistance was assumed to terminate, and Section 5 assistance was assumed to grow to $35 million based on an average of the assistance levels proposed in two bills presently before Congress.* State subsidies and outside community reimbursement were expected to grow at the assumed inflation rate. The apportionable deficit was then allocated to each town based on the present apportionment ratios.

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*A more recent amendment incorporated in the Senate bill as proposed by Senator Brooke would, if enacted, bring Section 5 assistance to over $60 million.

For the composite system, deficits were calculated in two ways, with bus service in certain corridors and alternatively with Plan A in these same corridors. Deficits due to bus service are calculated in a more complex manner than rail deficits. The primary factors affecting bus service deficits are the population of each community and the number of bus miles of revenue service in each community. Each of these two factors account for half of the apportionable deficit.

5.3 PLAN A

As described in Chapter 4, Plan A is a limited investment alternative, designed to provide "stop gap" continuation of service for 5 to 8 years. Capital investment objectives of this plan would be to treat most severe conditions and emphasize equipment.

5.3.1 Costs

System-wide, the total operating cost for Plan A is \$32,111,000, which is 7% less than the cost of operating the present system. Fixed costs total \$4,279,000, or 15% of the operating costs, with \$2,490,000, or 8%, being allocated overhead and \$24,872,000, or 77%, being the operating costs that vary with the level of service produced.

The estimated gross cost of operating the Plan A rail system on the Northside is \$18,551,000, or 13% less than the estimated gross cost of providing rail service in 1977. This decrease in operating cost is due primarily to the type of rolling stock used which in turn is reflected in maintenance of equipment costs (57% less than the present system). New and rebuilt locomotives, coaches leased from Toronto's "GO" commuter system, and a limited number (10) of passive RDC's (one-engine RDC's that are pulled by locomotives) will be used to provide service. The locomotives are significantly less costly to maintain than RDC's and only running repairs (which cost 81% less that it does to maintain an old RDC) have to be made on the leased coaches. Maintenance costs for passive RDC's are only slightly less than for an old two-engine RDC.

Another, although somewhat minor, contributing factor to the decrease in cost is the elimination of bridge-tenders associated with Draw 7 on the Eastern Route. It should be noted that the maintenance of equipment savings are moderated by higher fuel costs (\$0.90 per locomotive mile vs. \$0.31 per RDC mile) and coach leasing costs (\$24,000 annually per coach).

The estimated gross cost of operating the Plan A rail system on the Southside is $13,560,000 or 3% more than estimated 1977 operating costs. This slight increase is due primarily to higher fuel costs (more trips are operated than in the base case and most former RDC trips are now locomotive-coach trips), a higher passenger incentive* (due to a ridership increase), and a concomitant increase in overhead costs. It should be noted that maintenance of equipment costs are only slightly less than in the base case because passive RDC's are still assigned to the Needham Route which probably will be out of service under this alternative.

The Northside costs are: Transportation Department, $9,164,000; Mechanical Department, $2,914,000; Engineering Department, $3, 190,000; all other departments, passenger incentive, insurance and leasing costs, $3,283,000. The Southside costs are: Transportation Department, $6,346,000; Mechanical Department, $4,500,000; Engineering Department, $964,000; all other departments, insurance, passenger incentive and management fee, $1,851,000.

The total capital expenditure required to operate Plan A is $53,874,000. This total translates into an annualized capital cost of $5,883,000. On the Northside, a capital outlay of $38,453,000 would be required and $15,421,000 would be required on the Southside to operate under Plan A. Capital improvements include new equipment, improvements to bridges and tracks, signal renewal and a new Southside maintenance facility. As indicated by cost figures, a large portion of the right-of-way and physical improvements are programmed for the Northside of the system in Plan A.

5.3.2 Projected Ridership

As shown in Chapter 3, relatively minor service improvements have caused a large increase in ridership on the commuter rail system. Under this alternative programmed improvements will result in enhanced service reliability--average lateness improves by 65% on the Southside and 80% on the Northside. The only exceptions would be the Reading Line, where reliability improves 70%, and on the Rockport and Ipswich Branches of the Eastern Line, which improve 60%.

With these improvements it is projected that daily ridership system-wide would increase about 14.4%, with Northside ridership expected to increase 9.5%, and Southside, 19.8%. On a line-by-line basis, ridership on the Framingham and Franklin Lines would show the largest gains, increasing 31.7% and 22.5%, respectively. The Reading and Eastern Lines would show limited gains, increasing 5.4% and 2.7%

* Fee paid to the railroad operator for each passenger carried.

respectively. These limited increases are due to the minimal reliability improvements on these lines noted above. Since this plan was designed as a short-term alternative, its long-term growth potential was not analyzed.

5.3.3 Projected Revenues

An increase in revenue of $1,240,000 (13.9%) is projected systemwide for this alternative. Northside revenue would increase 10.2% or $550,000 and Southside revenue would be up 20.0% or $490,000. The largest percentage increases are expected on the Framingham (32.5%) and Franklin (22.2%). However, the largest absolute increase in revenues are projected for the Shore Line ($290,000) and New Hampshire Line ($230,000). The smallest relative and absolute increases are projected for the Reading ($60,000 or 5.3%) and Eastern Lines ($50,000 or 2.8%) under this alternative.

5.4 PLAN B

As described in Chapter 4, Plan B is a stabilized service alternative which was designed to provide a reliable service and a long-term committment to commuter rail. Capital investment objectives would be to make permanent investments in those areas which affect continuance or reliability of service and to emphasize on-train improvements.

5.4.1 Costs

System-wide, the gross operating cost under Plan B would be $30,530,000, which is 13% less than the cost of operating the present system. Fixed costs are $4,779,999 or 16% of the total costs; allocated overhead totals $2,457,000. or 8%; and $23,294,000, or 76%, would be the costs that vary with level of service provided.

Under this alternative the estimated gross costs of operating North and Southside commuter rail service are $17,801,000 and $12,729,000, respectively. Northside costs are 16% less than base (1977) costs; a decrease which is due almost entirely to a 49% decline in maintenance of equipment costs (even though more equipment is required). Only new and rebuilt locomotives and new coaches* will be used to provide service, as mentioned earlier in this report; this equipment is much less costly to maintain than the old RDC's used in the base case.

Southside costs are 3% less than operating costs in the base case. As in the Northside, maintenance of equipment costs are lower (19%) than in the base case, but these savings are tempered by increased insurance costs (more equipment is needed) and increased fuel costs.

*Some coaches would be converted Budd cars, in like-new condition.

The Northside costs are: Transportation Department, $9,137,000; Mechanical Department, $3,464,000; Engineering Department, $3,190,000; All other departments, passenger incentive and insurance, $2,010,000. Southside costs are: Transportation Department costs, $6,344,000; Mechanical Department, $3,677,000; Engineering Department, $864,000; all other departments, passenger incentives, insurance and management fee, $1,844,000.

The total capital outlay required to operate under Plan B is $149,167,000. This total cost would result in annualized capital cost of $14,309,000. Capital projects would include a maintenance facility, upgrade of tracks and bridges, signal renewal and new equipment. As in the previous alternative, a large portion of the capital improvements would be programmed for the Northside of the system. The total capital costs for the Northside and Southside under Plan B are $101,677,000 and $47,490,000, respectively.

5.4.2 Projected Ridership and Growth Potential

Implementing Plan B would result in improvements in line-haul travel times on most of the commuter rail lines. Line-haul time improvements would range from 25% on the Fitchburg Line and 18% on the New Hampshire Line, while at the other end of the spectrum Shore Line times would remain unchanged. In addition, under Plan B, service reliability (average lateness) is expected to improve 93% systemwide and service frequencies would improve only on the Framingham Line (17%) with an additional train put in service on the line.

These service improvements are expected to increase ridership systemwide an estimated 26% with Northside ridership increaseing 2,000 or 24% and Southside ridership up an estimated 1,885 persons or 27.5%. Under this alternative, Framingham (40%) and Franklin (31.2%) would have the greatest relative gains. The Shore Line (23.6%) and Reading Line (23.4%) showed the smallest relative gains but would have the largest absolute gains in daily ridership increasing 970 and 520 persons respectively.

Growth in the potential market, as derived from projected increases in downtown work trips, is shown in Table 5-6 for each corridor in both the near term (1985) and long term (2005). The growth rate is projected to be more rapid in the near term than in the following 20 years. The Northside market increases 17.4% in the near term and only an additional 4.6% in the long term. On the Southside, the near term growth is 14.3% and in the long term, an additional 7%. System-wide the growth is projected at 16% in the near term, and an additional 5.7% in the long term. The above suggests a post 1985 slowdown in population growth in the commuter rail suburbs as well as a somewhat decreasing orientation of work trips generated in these suburbs to downtown during this long term period.

	1977	Year 1985		Year 2005		
Northside	Estimated Plan B Ridership	Potential Ridership	Percent Change 1977-1985	Potential Ridership	Percent Change 1077-2005	Percent Change 1985-2005
Eastern	3190	3750	17.6	3810	19.4	1.6
Reading	2740	3290	20.1	3400	24.1	3.3
New Hampshire	2690	3100	15.2	3300	22.8	6.5
Fitchburg	1980	2310	16.6	2515	27.0	8.8
Subtotal	10600	12450	17.4	13025	23.0	4.6
Southside						
Framingham	1190	1280	7.6	1300	8.9	1.5
Needham	1850	1990	7.8	2180	17.9	9.5
Franklin	1660	1840	11.0	1960	18.1	6.5
Shore Line	4030	4870	20.7	5240	30.0	7.1
Subtotal	8730	9980	14.3	10680	22.2	7.0
System Total	19330	22430	16.0	23705	22.6	5.7

TABLE 5-6

GROWTH IN POTENTIAL MARKET - PLAN B

On a line by line basis, the Shore Line and Reading corridors show the greatest near term growth (20.7% and 20.1%, respectively), with the Framingham and Needham corridors showing the least growth. In the following 20 years the projected trends are somewhat reversed, with Needham showing the largest growth potential and Reading slowing down considerably. Over the entire 28 year time frame, the Shore Line and the Fitchburg corridors share the largest potential growth (30% and 27%). As noted in section 5.2.1 these figures do not attempt to predict any increases or decreases in market share due to the changing characteristics of competing modes, primarily auto, in each corridor.

5.4.3 Projected Revenues

By implementing Plan B, systemwide annual revenues would increase $2.27 million or 25.6% with Northside revenue up 2.4.% and Southside revenue up 27.5%. The Framingham and Franklin line would have the largest relative rise in revenue increasing 40% and 30.5% respectively, while the Shore Line ($500,000) and Eastern Line ($400,000) would generate the largest absolute increase in annual revenues. On the other hand, the Fitchburg and Reading Lines would generate the smallest relative increase in revenues up 23%.

5.5 PLAN C

As described in Chapter 4, Plan C is the most optimistic rail alternative, which was designed to significantly upgrade the rail system, to provide fast, frequent, and reliable service throughout, capital investment in Plan C would make permanent improvements to upgrade service to near rapid transit levels, including equipment, right-of-way, maintenance facilities, station modernization and expanded parking areas.

5.5.1 Costs

The estimated gross cost of operating the Plan C alternative system is $42,885,000 or 24% greater than current operating costs. This represents a 12% and 30% increase in Northside and Southside costs respectively, over estimated 1977 gross costs. The increase in Northside costs is moderated primarily by at least two factors. The first factor is the maintenance of equipment. It is interesting to note than Plan C requires 48% more equipment than was needed in the base case, however, Mechanical Department Costs are 10% less. This difference in costs

is due to the elimination of all Budd cars as such and the exclusive use of locomotives and coaches. The locomotives are still relatively costly to maintain, but maintaining a new coach costs approximately two thirds less than maintaining an old Budd car. The second factor is the decrease in the number of non-operating personnel needed because of the elimination of six signal towers and one drawbridge.

The Northside costs are as follows: Transportation Department, $12,596,000; Mechanical Department, $5,384,000; Engineering Department, $3,189,999; all other departments, insurance and passenger incentive, $2,921,000; total gross costs, $24,091,000. The Southside costs are: Transportation Department, $10,514,000; Mechanical Department, $4,872,000; Engineering Department, $864,000; all other departments, etc., $2,542,000; total gross costs, $18,792,000.

Fixed costs account for 10% of total gross costs, 83% of total costs vary with the service provided and the remaining 7% are allocated overhead costs. The estimated capital program required for this system is $330,375,000, or $31,344,000 per year annualized. The total capital expenditures on the Northside and Southside under Plan C are $235,436,000 and $94,927,000, respectively. This program includes many types of improvements - track, rolling stock, signals, bridges and maintenance facilities.

5.5.2 Projected Ridership and Growth Potential

Under Plan C, level of service improvements in the form of lowered line-haul times, increased service frequency and enhanced service reliability are expected on all lines in varying degrees (see Chapter 4 for description). As such, Plan C showed the largest gains in daily ridership relative to the other alternatives. It should be noted that to maintain consistency with the North Shore Transit Study, it was assumed that express bus service to the North Shore would be substantially cut back improving the market capture of commuter rail in this corridor. In addition, the ridership forecasts on several lines also reflect the impact of several new rail stations programmed under this alternative. There are three new rail stations on the New Hampshire Line (Tufts, Mishawum, and I-495/Lowell), two on the Shore Line (VFW Parkway and West Stoughton), and one on each of the Eastern (Chelsea) and Reading (I-93) and Framingham (West Natick) Lines.

By implementing Plan C, daily ridership would increase 12,500 or 85% over current daily boardings. (At a capital cost of $330 million in addition to over $100 million from CRIP and CRIP II.). The Northside ridership would increase 92% and the Southside 65.2%. This disparity is due to the special circumstances associated with the Eastern Line. The Eastern Line itself would have the largest absolute (4300) and relative increase (170%) of any single line.

The Eastern Line alone accounts for 37% of the total system-wide increase. Of the remaining lines, the New Hampshire (78.5%) and Franklin (72.3%) Lines would have the largest relative increase and Shore Line would have the largest absolute increase in daily riders (2150). The smallest increases would occur on the Needham (55.8%) and Fitchburg (46.2%) Lines.

Growth in the potential market for Plan C service is shown in Table 5-7. The projected pattern here is very similar, in terms of percentage growth, to the pattern shown for Plan B in Table 5-6. The absolute values are of course higher because of the higher estimated base year (1977) riders due to the better service. There are minor differences in the growth rates compared to Plan B because of minor differences in the composition of the Plan C market by municipality. Again, there is no attempt here to predict any change in market share due to changes in the characteristics of competing modes in each corridor.

5.5.3 Projected Revenues

Consistent with the large increase in ridership discussed above, Plan C would generate an equally large increase in annual revenue totaling $7.48 million or an 84.3% increase over recent annual revenues (1977). The Northside revenue would increase 96% and the Southside 65.8%. As in the case of ridership, the Eastern Line would generate the largest increase in revenue rising 169%. Of the remaining lines, the New Hampshire and Framingham Lines generate the largest relative increases in revenue gaining 78% and 73%, respectively. The smallest relative increases would occur on the Needham (54.8%) and Fitchburg (46%) Lines. In absolute terms the Shore Line would generate the largest increase in revenues ($1,130,000) and Framingham the smallest ($290,000).

	1977	Year 1985		Year 2005		
Northside	Estimated Plan C Ridership	Potential Ridership Plan C	Percent Change 1977-1985	Potential Ridership	Percent Change 1977-1985	Percent Change 1985-2005
Eastern	6860	7840	14.0	7890	15.0	0.06
Reading	3470	4170	20.2	4320	24.3	3.6
New Hampshire	3820	4430	15.8	4730	24.0	6.7
Fitchburg	2360	2800	18.7	3100	31.3	10.7
Subtotal	16510	19240	16.5	20040	21.3	4.2
Southside						
Framingham	1400	1490	6.4	1520	8.5	2.0
Needham	2220	2480	11.7	2620	18.0	5.6
Franklin	2180	2420	11.0	2590	18.8	7.0
Shore Line	5410	6550	21.1	7025	30.0	7.0
Subtotal	11210	12940	15.4	13755	22.7	6.3
System Total	27720	32180	16.1	33795	22.0	5.0

TABLE 5-7

GROWTH IN POTENTIAL MARKET - PLAN C

5.6 COMMUTER BUS ALTERNATIVE

As described in Chapter 4, the Commuter Bus Alternative was designed to provide commuter bus service that would replicate as much as possible the current commuter rail service. In some cases, this would provide a station with non-stop service to downtown, while in other cases it would provide service that stops in a few locations before travelling express to downtown. Some services would operate as shuttles to existing rapid transit services.

5.6.1 Costs

The estimated total gross cost of operating the commuter bus service is $18,136,000 (47% less than current costs) with Northside and Southside costs being $2,306,000 and $9,830,000 respectively. The breakdown of the Northside costs by department are: Transportation - $4,075,000; Mechanical (includes bus fuel costs) - $2,950,000; Engineering (includes the maintenance of bus shelters, stop signs, etc.) - $126,000; Insurance claims and damages - $179,000; Overhead - $976,000. The costs by category on the Southside are: Transportation - $4,424,000; Mechanical - $3,695,000; Engineering - $343,000; Insurance, claims and damages - $213,000; Overhead - $1,155,000.

Of the total operating costs, 12% is allocated overhead and 88% varies with the level of service provided. There are fixed costs associated with operating bus service, however, the number of bus routes operated by the MBTA makes it impossible to allocate them to specific routes. Further, many of the fixed costs associated with operating the bus service would be incurred only if such service were implemented in full. These costs relate primarily to the required new bus garages and terminal facilities, which would be sized to meet the amount of service to be offered. It can be seen from Table 5-3 that operation of the entire replacement bus system would result in a savings of $16,337,000.

In order to operate this system, the MBTA would need to purchase 262 new buses, build two new bus garages, and provide three new or rebuilt terminal facilities at a total capital cost of $31,460,000. This is an annualized cost of $3,904,000 (capital costs include cost for garage and terminal facilities).

5.6.2 Projected Ridership and Growth Potential

The existing highway system does not permit the Commuter Bus service to provide line-haul times comparable to the existing commuter rail system. This disparity is most notable along the Eastern Route and along the commuter rail lines in Boston's southwest corridor. On the Eastern and Franklin Lines, travel times at some points would

increase as much as 40% to 70% relative to present rail times. However, the commuter bus service that would operate in the Framingham and Fitchburg Line* corridors and in parts of the Needham and Reading Branch corridors would provide a level of service comparable to the present rail service.

Table 5-8 shows the growth in the potential market for commuter bus service. Again, there are similarities with the percentage growth projections for Plans B and C shown in Tables 5-6 and 5-7. In most cases the absolute values are lower because of the generally inferior bus service. Again there is no attempt to predict any changes in market share due to changes in the characteristics of competing modes.

5.6.3 Projected Revenues

Assuming the use of existing rail fare structures, the commuter bus alternative would result in a 46% system-wide reduction in annual revenues ($2.56 million). Northside and Southside revenue losses would be about 33% and 27%, respectively.

The decrease from recent annual (1977) levels of commuter rail revenues would amount to $790,000 on the Eastern Route, $570,000 on the New Hampshire, and $500,000 on the Shore Line. Smaller decreases would occur on the Reading ($190,000) and Fitchburg ($170,000) Lines, while revenues on the Framingham Line would increase $10,000.

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*with service on the Fitchburg Line running to Alewife Station on the Red Line extension

	1977	Year 1985		Year 2005		
Northside	Estimated Commuter Bus Ridership	Potential Ridership	Percent Changes 1977-1985	Potential Ridership	Percent Change 1977-1985	Percent Change 1985-2005
Eastern	1410	1660	17.7	1690	19.1	1.8
Reading	1860	2220	19.3	2300	23.6	3.5
New Hampshire	1250	1440	15.2	1530	22.4	6.3
Fitchburg	1360	1580	16.2	1750	28.7	10.7
Subtotal	5880	6900	17.3	7260	23.4	5.2
Southside						
Framingham	860	930	8.1	950	10.4	2.2
Needham	1150	1270	10.4	1350	17.4	6.3
Franklin	710	800	12.6	860	21.0	7.5
Shore Line	2320	2830	22.0	3030	30.6	7.1
Subtotal	5040	5830	15.8	6190	22.8	6.2
System Total	10,920	12,730	16.5	13,450	23.2	5.7

TABLE 5-8

GROWTH IN POTENTIAL MARKET - COMMUTER BUS

6.0 DETAILED ANALYSIS OF EACH LINE

6.1 INTRODUCTION

For each service corridor, three levels of investment in commuter rail, and one possible express bus alternative were examined in the CRIP Plan Refinement Study. Each of these alternatives was analyzed on a systemwide basis, a line-by-line basis and a regional impacts basis. This chapter deals with the line-by-line impacts, and makes recommendations to guide the development of a long-term commuter rail program. In some corridors, the need for capital investment is clear from the data presented. In other areas, operational changes must be brought about to test for possible positive market response.

Costs, ridership, and revenues were determined for each alternative, and are described in the previous chapter. Each commuter rail line was then analyzed separately with regard to the cost and ridership implications of adopting each level of investment or the commuter bus service. Both capital costs and net costs of service in relation to the ridership were important considerations in arriving at the findings. Evaluation criteria were set up based on these measures.

Each line was also evaluated in relation to impact on parking, traffic, and freight service in the region.

6.2 EVALUATION CRITERIA

As mentioned in Section 6.1, a set of criteria was used for assessing the efficiency and cost-effectiveness of each of the alternatives analyzed. The criteria used reflect the goals of minimizing costs while maximizing transit ridership. These criteria were applied on a line-by-line basis, and on a system-wide basis. The system-wide results were not an average of line-by-line results, since they incorporate fixed, system-wide operating costs and system-wide capital costs. Northside and Southside services were analyzed separately since all costs and revenues are separable and independent.

Cost figures used were capital costs, annualized capital costs and operating costs. The capital costs were based on MBTA commuter rail department estimates, which were

based on studies by consultants, or on recently bid construction contracts. Equipment costs were also based on recent contracts but were averaged by line to reflect a mix of new and old equipment. The calculation of operating costs is described in detail in Technical Appendix A, including the determination of train schedules, train miles, crew usage, and maintenance needs. Unit costs are all based on actual costs from the 1977 operation. Bus costs are based on operation by the MBTA even though in some cases the service would be operated by private carrier. As a result, bus costs portrayed in this analysis will tend to be higher than what might actually be experienced.

Ridership calculations are based on level of service and train reliability. The process of calculating ridership is described in Technical Appendix B. Revenues are calculated based on ridership and the average fare* at each station; they are annualized on a line-by-line basis.

All of the items mentioned above were used to calculate three cost-effectiveness measures - net cost of service per trip, annualized capital cost per new trip, and revenue-to-cost ratio. Net cost of service per trip represents the MBTA net deficit for each commuter rail rider. It equals the annual operating cost plus the debt service on the capital cost (20 percent of the annualized capital cost) minus the annual revenue, all divided by the number of fares paid (annual ridership). The second measure is indicative of the capital cost needed to attract each new rider, and equals the annualized capital cost divided by the difference between annual ridership for the alternative and annual ridership for the present system. The last measure is similar to an operating cost ratio, but it also includes debt service requirements. This measure is calculated by dividing revenue by the sum of operating cost and debt service on the capital cost.

6.3 DEVELOPMENT OF A COMPOSITE SYSTEM FOR IMPACT ANALYSIS

The data generated through the CRIP Plan Refinement Study reveals that the case for high priority capital investment is particularly strong in four corridors, and near-term capital programming efforts are expected to be consistent with these conclusions. In one corridor, the Needham Line, a test of express bus service will be necessitated by railroad reconstruction in the Southwest Corridor. On most other branches, capital improvement demands are relatively

* Average fare at each station is based on the various types of ticket purcheses recorded at each station, i.e. monthly tickets, one ride tickets, discount tickets, etc.

minor, and service decisions can be made on the basis of operating results. This document has not attempted to forecast the long-term facility decisions for each line--decisions which will be made in response to actual ridership and revenue data. However, it is necessary to document the economic and environmental implications of changing the configuration of the region's rail network. To illustrate the impact of cutting rail service, a composite network was created for testing. That network assumes rail cutbacks on the Gloucester Branch, the Reading Route and the Fitchburg Division. On the Southside, both the Framingham Line and the Needham Line are assumed to be served with express buses. This configuration was developed in the study to illustrate what was felt to be the maximum facility alteration still under policy consideration. The existence of a composite system for testing in no way implies a plan recommendation for a final network configuration. Such a final system would be the longterm result of line-by-line operating decisions made over the next decade. Table 6-1 summarizes the results of the evaluation analysis used in developing the composite system.

6.3.1 Eastern Route to Ipswich

Considerable capital investment is required to maintain rail operations on the Eastern Route Main Line. However, due to the lack of a free-flowing highway in the corridor, bus replacement service could attract only 55 percent of present rail riders. In addition, congestion on the Mystic River Bridge and Central Artery would be aggravated by the additional buses and autos if rail service were discontinued. Upgrading service to 1957 levels (Plan C) would cost almost $78 million. But, by providing commuter rail service frequencies of six minutes to Lynn, many of the present express bus routes from Lynn to Boston could be eliminated. Daily inbound ridership under this plan would be 6,680, and the net cost of service per trip is the lowest of any option ($1.86).

With the extension of Blue Line service to Lynn, six-minute headways on commuter rail are not justified; improvements should be made to the level of Plan B.

The available parking space at Beverly station is presently being fully utilized. An additional 50 spaces could be provided which would meet short-run increases in demand. However, the projected ridership under Plan C would require approximately 450 more spaces at Beverly and another 160 spaces at Swampscott.

	Present System	Plan A ("GO" [2] Coaches)	Plan B	Plan C	Commuter Bus
	(Fall 77)				
EASTERN [1]					
Capital Cost	---	26,657	46,811	101,383*	3,494
Inbound Riders	2,250	2,620	3,190	6,860	1,410
Revenue	1,768	1,816	2,212	4,756	977
Operating Cost	6,637	5,790	5,340	9,489	3,032
NCS/trip	3.33	3.06	2.20	1.70+	2.66
ACC/new trip	---	77.45	12.19	3.96	NM[3]
REV/(OC+.2ACC)	.266	.314	.355	.415	.312
READING					
Capital Cost	---	1,983	11,187	20,841	1,654
Inbound Riders	2,220	1,983	2,740	3,470	1,860
Revenue	1,115	1,175	1,377	1,743	934
Operating Cost	3,585	3,199	2,849	3,526	895
NCS/trip	1.98	1.58	1.09	1.13	0.00+
ACC/new trip	---	3.28	3.55	2.91	NM
REV/(OC+.2ACC)	.311	.362	.451	.443	.992
NEW HAMPSHIRE					
Capital Cost	---	3,988	17,723	40,651	2,943
Inbound Riders	2,140	2,510	2,690	3,820	1,250
Revenue	1,368	1,604	1,720	2,443	799
Operating Cost	4,401	3,744	3,820	4,968	2,840
NCS/trip	2.54	1.59	1.63	1.56+	3.05
ACC/new trip	---	1.94	5.57	4.23	NM
REV/(OC+.2ACC)	.311	.419	.413	.424	.273
FITCHBURG					
Capital Cost	---	5,825	18,719	46,210	1,746
Inbound Riders	1,600	1,890	1,980	2,340	1,360
Revenue	1,149	1,357	1,422	1,680	976
Operating Cost	3,535	2,763	2,738	3,604	1,539
NCS/trip	2.55	1.38	1.45	2.07	0.77+
ACC/new trip	---	3.40	8.03	10.39	NM
REV/(OC+.2ACC)	.325	.472	.460	.373	.615
N.SYSTEM					
Capital Cost	---	38,453	101,677	236,747	10,187
Inbound Riders	8,510	9,360	10,600	16,490	5,880
Revenue	5,400	5,952	6,731	10,622	3,686
Operating Cost	21,307	18,645	17,896	24,736	8,306
NCS/trip	3.29	2.55	2.18	2.00	1.47
ACC/new trip	---	8.91	8.15	5.05	NM
REV/(OC+.2ACC)	.253	.305	.339	.362	.429

1 Eastern Rte. figures include Gloucester Br. Tbl.6-2 shows Gloucester Br. separately

2 Includes leased Toronto "GO" Coaches

3 Due to ridership loss, calculation of this measure is not meaningful.

\+ Alternatives with lowest net cost of service per trip for each line. (excluding Plan A).

EVALUATION OF ALTERNATIVES: NORTHSIDE

TABLE 6-1 P.1

Key to abbreviations: NCS is net cost of service; REV is revenue; OC is operating cost; ACC is annualized (i.e. amortized) capital cost; .2ACC is the state and local share (20%) of ACC.

	Present System	Plan A[2] ("GO" Coaches)	Plan B	Plan C	Commuter Bus
FRAMINGHAM	(Fall 1977)				
Capital Cost	---	1,076	4,467	6,681	1,654
Inbound Riders	850	1,120	1,190	1,450	860
Revenue	402	530	563	686	407
Operating Cost	1,032	1,320	1,290	2,699	805
NCS/trip	1.43	1.40	1.32	2.85	0.99+
ACC/new trip	---	0.87	2.49	2.22	NM[3]
REV/(OC+.2ACC)	.390	.394	.408	.242	.478
NEEDHAM					
Capital Cost	---	2,616	13,432	19,223	1,471
Inbound Riders	1,470	1,720	1,850	2,270	1,150
Revenue	620	725	780	957	485
Operating Cost	2,582	3,859	2,872	3,446	861
NCS/trip	2.53	3.52	2.41	2.48	0.69+
ACC/new trip	---	2.06	6.50	5.60	NM
REV/(OC+.2ACC)	.240	.185	.249	.244	.538
FRANKLIN					
Capital Cost	---	2,539	8,349	22,810	2,389
Inbound Riders	1,265	1,550	1,660	2,180	710
Revenue	718	880	943	1,238	403
Operating Cost	1,707	1,683	1,775	3,139	2,386
NCS/trip	1.49	1.04	1.14+	1.87	5.49
ACC/new trip	---	1.72	3.90	2.52	NM
REV/(OC+.2ACC)	.421	.507	.487	.366	.164
SHORE LINE					
Capital Cost	---	3,690	15,742	28,014	5,609
Inbound Riders	3,260	3,810	4,030	5,410	2,320
Revenue	1,720	2,010	2,125	2,854	1,223
Operating Cost	6,122	4,974	5,067	7,784	5,778
NCS/trip	2,53	1.50	1.52+	1.89	3.81
ACC/new trip	---	1.42	3.83	2.30	NM
REV/(OC+.2ACC)	.281	.397	.395	.343	.206
S.SYSTEM					
Capital Cost	---	15,421	47,490	93,628	11,273
Inbound Riders	6,845	8,200	8,730	11,310	5,040
Revenue	3,460	4,145	4,411	5,735	2,518
Operating Cost	13,168	13,561	12,729	18,793	9,830
NCS/trip	2.68	2.24	2.00	2.46	2.86
ACC/new trip	2.68	2.20	4.65	3.58	NM
REV/(OC+.2ACC)	.263	.299	.323	.280	.248

2 Includes Leased Toronto "GO"Coaches.

3 Due to ridership loss in most cases, calculation of this measure is not meaningful.

+ Alternatives with lowest net cost of service per trip of each line (excluding Plan A).

EVALUATION OF ALTERNATIVES: SOUTHSIDE

Key to abbreviations: NCS is net cost of service; REV is revenue; OC is operating cost; ACC is annualized (i.e. amortized) capital cost; .2ACC is the state and local share (20%) of ACC.

TABLE 6-1 P.2

6.3.2 Gloucester Branch

The cost-effectiveness of investments in the Gloucester Branch is very low when compared to investments in other lines. Two factors contribute to this situation. First, the physical condition of the line is very poor with two bridges badly in need of reconstruction. Second, auto ownership in Rockport, Gloucester and Manchester is high; over 93 percent of the present Gloucester Branch riders have automobiles. Since Route 128 parallels the branch for most of its length it provides a good means of access to Eastern Main line stations. Therefore, the discontinuance of service on the branch would result in an estimated loss of less than 20 percent of the present 500 boardings, even if no buses or shuttle buses were provided. Development of additional Eastern Route parking with access from Route 128 would be important to the success of discontinuing service on this branch. But, even without that station, an estimated 65 percent of the Gloucester riders would continue to use commuter rail. Parking improvements on the Ipswich Branch would be required to accommodate this shifted demand. $11.2 million of capital and $0.83 million of operating costs per year would be saved by discontinuing service on this branch. Net cost of service per trip is almost $8.00, which is very high when compared to other lines. The costs of continuing service on the Gloucester Branch are provided in Table 6-2.

This line is currently under study for discontinuance of freight service by the B&M, as specified in the 1977 Massachusetts rail plan. Furthermore, it is a line noted by the B&M as a possible candidate for abandonment if commuter rail service is discontinued. Four or five shippers located in Gloucester and Rockport generate all of the freight using this line. Freight movement is minimal (about 300 carloads in 1976) and has decreased from 1972 to 1976. Track is in poor condition (Class 2). If this line is abandoned, it is likely that one of the shippers would be forced out of business.

6.3.3 Reading Branch

Bus service results in retention of 84 percent of present riders. In addition, the operating cost for new service would be nearly offset by revenues. Some refinement of the proposed bus schedules might show even more favorable results.

	Eastern Route Both Branches		Ipswich Br. Plan C w/o Gloucester	Ipswich Br. Plan C, Gloucester Plan B	Increment to Keep Gloucester in Service
	Plan B	Plan C			
Capital Cost ($ thousands)	46,811	101,383	77,727	88,921	11,994
Inbound Riders	3,190	6,860	6,537	6,740	203
Revenue ($ thousands)	2,212	4,756	4,502	4,672	170
Operating Cost ($ thousands)	5,340	9,489	7,616	8,441	825
NCS/trip ($'s)	2.20	1.70	1.24	1.44	7.71
ACC/new trip ($'s)	12.19	3.96	3.29	3.57	9.94
REV/(OC+.2ACC)	.355	.415	.494	.460	.161

TABLE 6-2

EVALUATION OF GLOUCESTER BRANCH

Continuation of rail service requires less capital than on any other line (except the Framingham and Franklin lines, which are both special cases), and the net cost of service per trip is the lowest in the region. However, due to competition from I-93 and the Orange Line, ridership on the Reading Line continues to decline, decreasing by one third since 1974, an annual rate of decline of more than seven percent.

The net impact of all of these factors indicates that even though rail service performs well now, its operating efficiency will probably decline in the future.

As the MBTA acquires new equipment, including coaches proposed to be leased from Toronto on an interim basis, it will be possible to offer an improved service. The results of these improvements should be monitored closely over a two-year period and reviewed. Plans should be developed for providing bus service at the end of this period if such action should be indicated on the basis of this review.

Presently, an average of 11 shippers use the freight service on this line, and carloads handled have decreased significantly from 1972 to 1976.[1] Track conditions are between Classes 2 and 3 (speeds of up to 50 mph). The B&M mentioned this line as a possible candidate for abandonment if commuter rail service is eliminated. However, most of the freight is handled on the inner segment of the line, which is less likely to be abandoned.

If bus service on the Reading Branch was operated as a replacement service for rail, there would be an impact on parking at the Oak Grove, Wellington and Sullivan Square Orange Line stations. With the construction of the Mishawum station on the New Hampshire Line, the transfer of commuter rail riders to the Orange Line would be small; without the new station there would be some increase in parking demand at Oak Grove (30 cars), Wellington (five cars), and Sullivan Square (13 cars). This increase in demand would cause a problem at Sullivan since current parkings needs exceed the capacity at the station.

1 Carloads have decreased by 37 percent, from 2,600 to 1,600, on the Western Route Main Line (Medford to Lowell Jct.). However, these figures do not include the carloads handled in Medford, Edgeworth and Lowell Jct., due to insufficient data sources.

6.3.4 New Hampshire Division

Bus service in this corridor does not do very well, while improving the rail service would increase ridership from 25 to 80 percent. It is recommended that the right-of-way be improved to the Plan B level, while equipment and service should be improved to a Plan C level. Hence, less capital investments would be required than for the full Plan C level. Still, an estimated 74 percent increase in ridership would result. Improvement to this level reduces net cost of service per trip to $1.48, and increases revenues to cover over 44 percent of the operating costs plus debt service.

Parking space is being well utilized at stations on this line. The increase in ridership projected under Plan C service levels will require additional parking. At Wilmington and North Billerica, there is sufficient space available through new or expanded lots to accommodate these increases. However, at Winchester and Wedgemere, 85-90 new spaces will be needed, and at Lowell increased ridership will require 165 more spaces.

6.3.5 Fitchburg Route

Direct bus service to downtown Boston performs very poorly in this corridor, but bus service to an Alewife station on the Red Line is a strong alternative to commuter rail service. Hence, any switchover to bus is not feasible at least until that station is open.

Another factor of importance is that a rapid transit station at Alewife would attract commuter rail patrons to the Red Line. However, the transfer station at Porter Square could counterbalance this impact. An alternative bus service could have this same result. Further analysis should await the opening of the Red Line so that the evaluation can be based on the actual rather than the projected impacts of the Red Line extension. Limited investments (Plan A) should be made in order to maintain service at current levels.

It is likely that freight service will continue on the Fitchburg route no matter what happens with commuter rail or rapid transit service. The B&M was questioned concerning the importance of commuter rail to continuance of freight service, and the Fitchburg line was one which they mentioned would remain in service. This is reinforced by the fact that freight movements remained relatively constant from 1972 to 1976 while declining on other B&M lines. However, the overall condition of the track on this line is not good, as indicated by maximum allowable passenger speeds of 25-40 mph. Therefore it could not remain in service for an extended period without increased maintenance.

The Fitchburg line has been a main freight route for the B&M, but much of this freight will be shifted to the New Hampshire Division as construction of the Red Line progresses. Nevertheless, the West Cambridge yards will remain active and the Fitchburg Route will still be used as access to those yards.

The implementation of replacement bus service on the Fitchburg Line would result in a slight increase in parking demand at Riverside (five cars). Even if the increase is larger, there would be little strain on Riverside parking since proposed improvements to Riverside should provide for this potential increase.

If service on the Fitchburg Line is replaced by buses when the proposed Alewife station opens, there may be an increase in parking demand at that station. Parking is expected to be tight at this new location, and additional cars from former commuter rail riders who drive to the station could not be accommodated.

Any increases in ridership on the Fitchburg line would aggravate the tight parking which currently exists at Concord and West Concord. Additional parking space can be made available through new or expanded lots at both of these stations and would be sufficient to accommodate any new spaces needed no matter what level of service improvement is eventually made to the line (up to Plan C, which would require 45-65 new spaces).

6.3.6 Framingham Line

Even though most right-of-way costs are being taken care of by ConRail, replacement bus service is a more cost-effective alternative to improved rail service. The existence of a free-flowing highway in the corridor greatly benefits the bus alternative. Further, private carrier bus service already exists, and its expansion to serve the downtowns of the Western corridor suburbs would further improve the economics of bus service, since private carriers have lower operating costs than the MBTA. A trial period should be used to determine if the cost-effectiveness of the rail alternative can be improved and to gauge the success of new equipment in attracting riders. This trial should not be very costly since the right-of-way requires little or no expense.

Because of its status as the major freight route in Massachusetts, this line will be maintained regardless of the status of commuter rail. Presently, ConRail is installing welded rail on most of the right-of-way. This is an obvious commitment to long-term continuation of freight service on this line.

Commuter bus service would carry at least as many patrons as the present rail service. Hence, no increase in parking demand at any rapid transit station would be likely as a result of replacing rail with bus.

Any increases in ridership resulting from the rail experiments proposed for this line may create parking demands which cannot be met at certain stations. This is particularly true for Natick and Framingham, where no parking is currently available. Plan A improvements would result in a deficit of 34 spaces at Natick and 90 at Framingham.

6.3.7 Needham Branch

Economic and statistical analyses indicate that bus service is a very efficient option in this corridor. Since construction of the relocated Orange Line will require bus service to be operated during the construction period, that bus service should be tested during a two-year trial period to confirm or refute these results. If the bus service proves to be unsuccessful, the railroad should be restored to Plan B levels.

There is presently no freight service on this line from Forest Hills to Needham Junction. Freight service on the segment from Needham Junction to Needham Heights will most likely be continued even if commuter service is terminated.

Commuter bus lines would result in an increase in demand for parking at both Riverside and Forest Hills. The increase would be for approximately 25 spaces at each location.

6.3.8 Franklin Branch

Many dollars have already been spent to upgrade the Franklin Branch right-of-way. Further, commuter bus service in this corridor would be less cost-effective than in any other corridor, with a net cost of service per trip of almost $5.50. Additional work should be done to bring the railroad to the level of Plan B. Extra equipment should be made available to increase frequencies as ridership responds to improvements.

Parking at the three inner stations of Endicott, Islington and Norwood is currently at or beyond capacity. To meet the parking needs for ridership projected under Plan B, a small number of new spaces (10-20) will be required at Endicott and Islington and about 50-60 will be required at Norwood. Presently, there is sufficient parking available at Walpole and Norfolk. The small increases in parking demand expected at these stations is within their available capacity.

6.3.9 Shore Line

Again, Plan B is the preferred option; it shows a net cost of service per trip of $1.52. However, there is a significant opportunity to increase ridership (by an additional 42 percent) if equipment is available to improve frequencies. The only non-equipment costs on this line are for the Stoughton Branch ($2.25 million), and for parking improvements.

Presently, parking space demand exceeds the supply available at Attleboro, Mansfield, Stoughton, Canton and Sharon; at Canton Junction, parking is almost at capacity. The expected increase in demand at Canton and Canton Junction can be met through new or expanded lots. However, increased demand at Sharon will require 105 spaces; at Mansfield, 205 spaces; at Stoughton, 95 spaces; and at Attleboro, 100 spaces. At Sharon, Stoughton and Attleboro, some spaces can be made available through new or expanded lots, but not enough to fully meet expected demand.

7.0 IMPACTS OF THE COMPOSITE SYSTEM

This chapter discusses impacts. It should be understood that the recommended program of service testing and initial capital investment could result in any of several possible long term system configurations. The preceding chapter has recommended that certain lines be upgraded to Plan B or C levels, that others receive investment necessary to keep them in service during a period of trial, and that one line's temporary substitute bus service (Needham's) be evaluated after a similar trial period. In order to evaluate the potential impacts of the outcome and end of this trial period the study has examined the impacts of one possible "composite system" which includes some rail cut-backs and some major CRR line upgradings and some commuter bus service. This system was chosen for illustrative testing because it reflects a logical maximum amount of facility change from the existing conditions. It does not represent a policy or program recommendation.

The composite system consists of commuter bus service on the Reading, Fitchburg, Framingham and Needham lines and various levels of rail improvements (specified in Chapter 6) on the Eastern, New Hampshire, Franklin and Shore Lines. Improved service on the Eastern Main Line, and parking at Route 128 provide alternate service for the Gloucester Branch. This system was used as the basis for determining the impacts which are described in this chapter. Based on this service configuration, the following sections examine the composite system, impacts on service operation, the physical and natural environment, the regional economy and on persons with mobility handicaps.

7.1 SERVICE OPERATION IMPACTS

This section examines the impacts of the composite system on ridership revenues and operating cost and efficiency on both the Northside and Southside systems. Table 7-1 presents the computed indices associated with each rail corridor under the present and composite system configuration (as described in Chapter 6) as well as the Northside and Southside aggregate totals. For a description of these measures and how they were computed refer to sections 5.2 and 6.2 and 6.3 of this report.

Looking first at the Northside totals, the composite system is expected to carry an additional 5100 patrons daily which is a 41% increase over the present system. In turn, annual revenues would also increase from $5.4 to $8.8 million while annual operating costs would drop from $21.3 to $17.5 million. Increased revenues coupled with lower operating costs would improve operating efficiency as indicated by the cost-effectiveness measures. Annual revenues per dollar of annual cost would improve from .253 to .438 and the net cost for each trip would drop from $3.29 and $1.50. The total capital outlay necessary to provide service under the Northside composite system is $136 million.

On the Southside, daily ridership under the composite system is projected to increase by 1000 persons or 14.7% over the present system. As shown in Table 7-1, annual revenues would increase from $3.5 to $4 million and annual operating costs would fall from $13.2 to $10.2 million. Accordingly, operating efficiency would improve with revenues per dollar of operating cost increasing from .26 to .36 and the net cost of service per trip falling from $2.68 to $1.70. The total capital outlay required to provide service under the Southside composite system is $32 million.

In summary, the composite system would have a positive impact on ridership, revenues and cost-effectiveness on both the Northside and Southside. The Southside impacts would be more moderate relative to those indicated on the Northside.

7.2 ENVIRONMENTAL IMPACTS

This section examines the impacts of the composite system on highway and downtown street congestion, the need for bus terminal facilities, downtown parking, vehicle miles travelled in the region, fuel consumption and pollutant emissions.

7.2.1 Access Highways

The composite system would have an impact on selected streets and highways in the region. However, on a region-wide basis increases in traffic on some routes would be off set by decreases on other routes. The traffic increases would result from former rail riders who switch to commuter bus and auto use in some corridors while traffic decreases would result from auto users who are diverted to the upgraded commuter rail lines.

NORTHSIDE

PRESENT SYSTEM (1977)	EASTERN	READING	NEW HAMPSHIRE	FITCHBURG	NORTHSIDE SYSTEM
Capital Cost	---	---	---	---	---
Inbound Riders	2,250	2,220	2,140	1,600	8,510
Revenue	1,768	1,115	1,368	1,149	5,400
Operating Cost	6,637	3,585	4,401	3,535	21,307
NCS/trip	3.33	1.98	2.54	2.55	3.29
REV/(OC+.2ACC)	.266	.311	.311	.325	.253

COMPOSITE SYSTEM (1977)	Plan C (No Gloucester	Bus	Plan B	Bus (Alewife)	Composite
Capital Cost	77,727	1,654	40,651	1,746	135,640
Inbound Riders	6,534	1,860	3,820	1,360	13,580
Revenue	4,502	934	2,443	976	8,850
Operating Cost	7,616	895	4,968	1,539	17,522
NCS/trip	1.24	0.00	1.56	0.77	1.50
REV/(OC+.2ACC)	.494	.992	.424	.615	.438

SOUTHSIDE

PRESENT SYSTEM (1977)	FRAMINGHAM	NEEDHAM	FRANKLIN	SHORE LINE	SOUTHSIDE SYSTEM
Capital Cost	---	---	---	---	---
Inbound Riders	850	1,470	1,265	3,260	6,845
Revenue	402	620	718	1,720	3,460
Operating Cost	1,032	2,582	1,707	6,122	13,168
NCS/trip	1.43	2.53	1.49	2.53	2.68
REV/(OC+.2ACC)	.390	.240	.421	.281	.263

COMPOSITE SYSTEM (1977)	Bus	Bus	Plan B	Plan B	Composite
Capital Cost	1,654	1,471	8,349	15,740	32,716
Inbound Riders	860	1,150	1,660	4,030	7,700
Revenue	407	485	943	2,125	3,960
Operating Cost	805	861	1,775	5,067	10,233
NCS/trip	0.99	0.69	1.14	1.52	1.70
REV/(OC+.2ACC)	.478	.538	.487	.395	.363

SYSTEMWIDE COSTS, RIDERSHIP, REVENUES AND COST-EFFECTIVENESS

TABLE 7-1

Commuter bus service would primarily affect traffic on I-93, the Central Artery, Route 2, Storrow Drive and the Massachusetts Turnpike.

Buses from the Reading Station would approach Haymarket Square via I-93 and the Central Artery. The peak hour volume of six buses would not increase congestion on these routes. Auto traffic on I-93 and the Mystic River Bridge would remain nearly the same due to the counter-balancing effects of the composite system.

Rail service on the Fitchburg Route will continue in the short-term. In the long term, the majority of inbound buses serving the Fitchburg line would be routed to the new Alewife Station on the Red Line extension. These buses would approach the station from Route 2. Increased auto traffic on Route 2 and Storrow Drive would be 100 cars in the peak hour.

Bus service for the Framingham and Needham routes would approach Boston via the Massachusetts Turnpike. The Turnpike normally operates well below capacity so that the additional peak hour buses using this route should cause no problem. The increase in auto traffic would be minimal. A special purpose lane could ensure continued free-flow traffic on the Turnpike in the long term.

In summary, the number of buses that would use access highways during peak periods is not substantial enough to cause traffic problems. Furthermore, the anticipated peak period increases in auto traffic should only have a minor impact on existing traffic flows.

7.2.2 Downtown Streets

Commuter buses would operate to the vicinity of Haymarket, South Station and Copley Square. To reach these destinations they would travel primarily over New Chardon, New Congress, New Sudbury and Federal Streets to the Haymarket bus terminal; Kneeland Street and Atlantic Avenue to South Station; and Dartmouth Street to Copley Square.

At the present time there is very little peak period congestion on the streets required to access the Haymarket Station. During the peak ten minutes eight buses would be arriving at the station.

Buses going to the South Station area and arriving via the Massachusetts Turnpike would cause or encounter no local street congestion, since the Turnpike's ramp is almost at South Station. However, those buses which would serve both South Station and Copley Square might affect Stuart/Eliot Street, Park Square and St. James Avenue. Since buses

follow this routing during the peak hour, efforts must be made to alleviate any congestion problems. A rebuilt Park Square, which is part of the Park Plaza project, could be designed to alleviate one congestion point while the planned traffic signal at Arlington Street would remedy any problems encountered there.

In the Copley Square area, buses could terminate at an on-street site at St. James Avenue, across from the Copley Plaza Hotel. In travelling to the St. James Avenue site, the one potential cause of congestion is the left turn onto Dartmouth Street from the Massachusetts Turnpike exit ramp. This can be relieved by some simple traffic engineering.

7.2.3 Downtown Parking

Those present commuter rail riders who could not use the four commuter bus services would result in approximately 400 additional cars destined for the Boston CBD. At the present time there is not enough parking available in many areas of the city where these new autos would be destined.

The largest number of additional cars (190) would go to the area centering on South Station and the next largest impact (80 cars) during the peak period, would be in the area centering on the Prudential and John Hancock buildings and Government Center. Once again, it should be noted that these additional parking demands would in large part be counter-balanced by the decreased parking needs of auto users from other corridors who are diverted to the upgraded commuter rail lines. There may be some shifts in parking demand but the overall impact on downtown Boston would be negligible.

7.2.4 Terminal Facilities

Buses serving the Reading Station would terminate at Haymarket while other bus service for the Reading Line would operate to Oak Grove. When the extension of the Red Line to Alewife is completed, most of the bus service for Fitchburg would terminate at Alewife and a portion would operate to Harvard Square and Post Office Square. Most of the bus service for the Framingham and Needham Lines would terminate at South Station or Copley Square.

During the peak hour, 8:00 to 9:00 AM, eight buses would be scheduled to arrive at Haymarket (one bus every ten minutes from Reading, and one bus at 8:00 and 8:30 from Kendall Green). The existing Haymarket Square bus loading area is already operating at capacity during peak hours, and certain MBTA and private carrier routes have to make curbside stops outside the busway.

Currently, 25 MBTA express buses and 21 local buses are scheduled to stop at the Haymarket busway between 8:00 and 9:00 AM. The bus service specified under the composite system would increase congestion at this terminal: this would require a new, enlarged terminal or revised circulation patterns on the roads near the existing terminal to accommodate the demands of eight additional buses during the peak hour.

On the Southside, 17 additional buses would arrive at both South Station and Copley Square during the peak hour, or an average of one every 3½ minutes. The heaviest ten minutes at South Station would be 8:20 to 8:30, when four buses would be scheduled to arrive. At Copley Square the peak ten minutes would be from 8:30 to 8:40 when five buses would arrive.

The existing South Station busway is located off Atlantic Avenue on a site formerly occupied by railroad tracks. The busway is designed for run-through operation, and has two platforms, each capable of accommodating 13 to 14 buses. The main user of the busway is the Plymouth and Brockton Street Railway Company. The Gray Line and Greyhound also route some buses there. Ten berths are used for current P&B operations. When the busway was designed, the MBTA was planning to terminate its Massachusetts Turnpike buses there, but because of objections from riders the terminal was left at Chauncy Street. Thus, the busway has considerable excess capacity and could accommodate the additional buses from the Framingham and Needham service. The design for the South Station complex being prepared in cooperation with the Northeast Corridor Improvement Program should be made to accommodate this.

All commuter trains on the Southside stop at Back Bay as well as South Station. In the analysis it was assumed that bus service for Bacy Bay Station would be provided by a terminal in the Copley Square area. Location requirements for this station are complicated by the fact that some buses would approach from the Massachusetts Turnpike and Terminate at Copley, some would approach from the Turnpike and continue to South Station, some would approach from South Station and continue to the Turnpike. Therefore this site must have good access to and from the Turnpike and to and from roads leading to South Station.

The site which best meets this requirement is on St. James Avenue next to the Plaza at Copley Square. Although this site is already being used for existing buses, a great increase in the number of buses stopping here might meet some community opposition.

The St. James Avenue site could accommodate six buses, which is sufficient to handle the commuter buses during the peak period. Some conflicts might arise with sight-seeing buses that presently use the site, but since most of these operate during off-peak hours, the conflicts would be minimal. The only capital cost required for the use of this site would be for a passenger shelter.

7.2.5 Vehicle Miles of Travel (VMT's) Fuel Consumption and Emissions

Under a composite system annual VMT's by autos would increase by 7.73 million in corridors served by the Reading, Fitchburg, Framingham and Needham Lines. Annual bus VMT increases would equal 1.33 million. The increases in auto VMT's would be balanced against decreases in other corridors (44.0 million VMT's) for a net regional decrease in auto VMT's of 36.3 million. Line by line estimates are provided in Table 7-2.

Overall regional fuel consumption by autos would decrease by 2.13 million gallons per year while diesel fuel consumption by buses would increase by 183,000 gallons per year.

On a regional basis, annual emissions would decrease as follows: hydrocarbons (HC) - 261.9 tons; carbon monoxide (CO) - 3594.5 tons; and nitrous oxide (NOX) - 100.4 tons. However, on a corridor basis the impact would vary substantially.

In analyzing the impact of a composite system on fuel consumption and emissions, the effect of changes in rail VMT's over present levels was not measured. Therefore, any increases in rail VMT's would result in additional regional fuel consumption and emission impacts.

7.3 ECONOMIC IMPACTS

7.3.1 Encouragement of Development

- Inter-Region vs. Intra-Region

Since transportation is one of a number of factors which affects development patterns, any improvement to a region's transportation system by itself is usually not responsible for generating new development. It can reinforce existing patterns and by working in conjunction with other factors help to shape the pattern of future growth. Therefore, development which is linked to improved transportation facilities represents a shift rather than an absolute change in a region's level of economic activity. This is borne out by studies of transit system improvements in both the U.S. and Canada. Commuter rail improvements,

	Increases in Annual Vehicle-Miles of Travel (thousands)		Increases in Annual Fuel Consumption (thousands of gallons)		Increases in Annual Pollutant Emissions		
	Auto	Bus	Auto	Bus	Hydro-carbons (HC)	Carbon monoxide (CO)	Nitrous oxide (NOX)
Northside							
Eastern	(13,705)*	—	(807)	—	(101.2)	(1,366.3)	(48.7)
Reading	2,886	218	169	39	22.1	296.5	15.1
New Hampshire	(15,892)	—	(937)	—	(117.3)	(1,594.0)	(56.5)
Fitchburg	2,220	523	131	50	18.2	231.1	18.9
NORTHSIDE TOTAL	(24,491)	741	(1,444)	89	(178.2)	(2,432.7)	(71.2)
Southside							
Framingham	199	329	12	51	2.9	27.8	7.5
Needham	2,425	262	143	44	19.3	250.8	14.4
Franklin	(4,151)	—	(245)	—	(30.6)	(416.4)	(14.8)
Shore Line	(10,268)	—	(601)	—	(75.3)	(1,024.0)	(36.3)
SOUTHSIDE TOTAL	(11,795)	591	(691)	95	(83.7)	(1,161.8)	(29.2)
SYSTEM-WIDE TOTAL	(36,286)	1,332	(2,135)	184	(261.9)	(3,594.5)	(100.4)

*Parentheses denote a decrease in that measure.

TABLE 7-2

ENVIRONMENTAL IMPACTS OF COMPOSITE SYSTEM - 1978

such as those specified in the composite system can work in a similar manner to shape the region's growth and thereby support the state's growth policy.

Two goals of the state's growth policy are to rehabilitate economically depressed areas and promote higher levels of economic growth. They translate into objectives such as the stabilization of neighborhoods and the promotion of development in proximity to existing activity centers. Improvements to the transit system which increase accessibility between Boston and suburban areas would reinforce the economic stability of these areas and help revitalization efforts. Furthermore, since the commuter rail system already links a number of town centers with the Boston CBD, future development is encouraged to focus on these areas. By reinforcing development in existing centers, commuter rail would also help to curb haphazard growth and the resulting increased demand for infra-structure investments. This is in line with another goal of the state growth policy, namely, to promote more efficient use of physical and natural resources.

Even though commuter rail improvements will support the state's growth policy, the service orientation of these changes make it unlikely that any significant development impacts would be immediately forthcoming.

- Impacts on Land Use Categories

There is very little evidence of land use impacts related to commuter rail system improvements. However, one example is found in Toronto's "GO" commuter rail system which began operations in 1967. It has been credited with encouraging a small amount of development, namely one apartment building and a commercial-retail mall near one of the "GO" stations.

The case of Philadelphia offers an illustration of the potential impact of an existing commuter rail system. In metropolitan Philadelphia, the commuter rail network has not been substantially altered in the last twenty years. However, major service improvements involving the purchase of new equipment and increased service frequency have been underway since 1960. These have resulted in significant ridership increases and some associated apartment and commercial developments around selected commuter rail stations. But in most of the areas served by the system impacts were insignificant, in part due to the well-established nature of these areas. Boston's rail system, and many of the proposed improvements are quite similar to the experience of Philadelphia.

In most cases, development linked to transportation improvements takes the form of office or residential use and, less frequently, retail facilities. It is the

characteristics of certain forms of transportation such as rail rapid transit with the high ridership levels and frequent service which makes them more likely initiators of development impacts than commuter rail systems.

- <u>Potential Impact of the Composite System</u>

Considering that the composite system uses two basic types of transit, an express bus system and a commuter rail system, it is likely that the latter of the two has a greater potential for encouraging some development. Although there is very little evidence of the differential land use impacts of various transit modes, the very nature of an express bus system suggests that it will have little influence on land development. First of all, a bus system does not have the same perceived degree of permanence as a fixed rail system, since bus routes can easily be changed, and existing highways are used as rights-of-way. Therefore, it is unlikely that the same focusing of development evident with fixed rail systems would result from the initiation of an express bus service.

Given that the commuter rail system has potential for influencing development in present market areas, the extent of that development is dependent on ridership levels and other factors affecting growth. The greatest potential is for some small scale growth around new stations if promoted by the local communities. If ridership levels increase significantly it is possible for some small, convenience retail facilities to locate in proximity to existing stations.

An improved commuter rail system may not have a significant impact on Boston CBD land uses because of other factors involved in development decisions but it does serve as a positive reenforcement of the area's viability for existing businesses. The decrease in accessibility to downtown that would result from the termination of commuter rail service might bring some businesses to the point where they decide to leave the city.

The most likely areas to experience increases in development in conjunction with commuter rail improvements are those areas adjacent to the proposed new commuter rail stations along Route 128 (Mishawum) and Route 495 (Lowell). If there is sufficient demand in these areas, some new housing may be constructed near the rail stations. Such a development would have the advantage of good highway and transit access to both the Boston CBD and other suburban areas.

7.3.2 Impacts on Freight Service

The termination of selected commuter rail lines in the composite system would have no impact on freight service provided by Conrail but would affect service on two B&M lines - the Gloucester and the Reading. Sixteen B&M customers might lose rail freight service compared to about 90 who might lost service if all commuter rail service were discontinued. This is based on information supplied by B&M which specified that the discontinuance of all commuter service would result in many of their lines becoming candidates for abandonment (the New Hampshire, the Eastern Route to Beverly, Fitchburg and Saugus lines would be retained). Conrail's freight operations would not be significantly affected by a termination of all commuter rail service. The impact of any discontinued commuter service on freight service and the regional economy would need to be analyzed in greater detail than is possible within the confines of this study.

The abandonment of freight service can have a negative impact on the operations of the 16 firms served by the Gloucester and Reading lines. This impact can range from small increases in transport costs to operational cutbacks to the actual closing down of businesses. In large part, the extent of this impact is dependent on the type of activity in which the rail users are engaged and the type of goods being transported by rail.

Bulky low value per weight commodities being shipped long distances tend to move by rail. Some of these commodities are also very dependent on rail because their size precludes shipment by highway and local roads. In contrast, those products currently being shipped by rail which are of high value per weight or light and compact could probably switch to truck service without a significant impact on the affected receivers' business operations.

In a Harbridge House study a comparison was made of industry groups according to the number of rail-related jobs and the number of potential job losses should all rail service by discontinued. The study found that eleven of the twenty industry groups with the greatest number of rail-related jobs were also among the top twenty in terms of potential job losses. Industry groups which ranked high in terms of both criteria were paper products, plastics and machinery, indicating a critical dependence on rail. In contrast, there are several industry groups such as toys, electrical equipment, and processed milk products which have a large number of rail-related jobs but low potential job losses. This indicates that an abandonment of rail service would not have a detrimental effect on their operations.

As previously mentioned, the Gloucester and Reading Lines could lose freight service if commuter rail is terminated on these same lines. Freight moving along the Gloucester Branch includes such items as chemicals, food stuffs and steel and on the Reading Branch - paper, chemicals, food stuffs, lumber, plastics and roofing material. Paper products and plastics are two industry groups which are very dependent on rail service. Therefore, the operations of some of the 16 firms using these lines might be severely affected if it was necessary for them to receive their shipments by truck rather than rail.

One measurement of the impact on the region's economy is the number of jobs that would be lost. Based on a study completed in 1975* the abandonment of freight service on the Reading and Gloucester lines could result is a loss of 200-230 and 630-730 jobs on the respective lines. These figures include both railroad jobs and jobs in firms using rail freight service and have been adjusted to reflect the decline in freight levels from the 1972 base used in the study. They represent the maximum that could be lost, if the affected firms are unable to find acceptable alternative freight shipping service. The Harbridge House study did anticipate additional jobs losses on the Boston to Somerville segment of the Reading Line. The proximity of this segment to the Boston area suggests that its freight service is not as closely tied to the continuation of commuter service as is the freight service on the outer segments of the Reading Line. Firms in the Boston/Somerville area might be served as offshoots of other rail freight service in the Boston area therefore the job losses associated with firms in this area should not be directly linked to the loss of Reading commuter service. In addition to a direct job loss, there would also be jobs lost in firms which interact with rail-using establishments. For example, suppliers of goods to industries using rail may have to curtain production because of decreased demand and therefore lay off a certain number of their labor force. In the aforementioned study it is estimated that for each initial rail-related job another 1.5 jobs would be lost in the region. These losses would be in addition to the direct potential job losses estimated above.

* The 1975 Harbridge House Study for the New England Regional Commission entitled "The Economic Impact of Rail Service in New England" estimated the potential job losses resulting from the abandonment of rail service in New England (based on 1972 tonnage data and shipper survey responses). The study showed the following potential job losses: Somerville yards area - 1500, remainder of Reading Branch - 330, Gloucester Branch - 1045.

Any direct job losses represent the short term impact of abandoning rail service on a particular segment. In the long run, some of the jobs may be regained in the form of newly created employment in another part of the region or in other firms in the same area. For example, some rail users adversely affected by rail service termination may decide to relocate elsewhere in the region where rail service is still available. Other lost jobs will reappear in the form of employment increases in other firms providing freight service in the region. Therefore on a statewide or regionwide basis, a short-term job loss of 830-960 would mainly be cancelled out in the long-term by other newly created jobs.

Job losses also result in lost wages and reduction in value added from decreased production. The previously mentioned Harbridge House study estimated the potential value that would be lost to the New England economy.* Based on 1977 wage and price levels the loss in value added would be $22,000 per job. Again this effect would be moderate in the long-term as firms readjust their operations.

7.3.3 Economic Impact of Commuter Rail Capital Investments

Capital investments in the commuter rail system will generate jobs and income in Massachusetts. These expenditures will provide jobs in those firms directly supplying the goods and services needed to improve the rail system and produce secondary effects in other sectors of the state's economy.

In estimating these impacts it is assumed that all equipment and about 50% of track improvements will involve out of state purchases and as such will have no direct impact on the state's economy. The primary economic impact of the composite system ** is due to $58 million in capital expenditures. It is estimated that this investment will result in a total statewide impact of $100 million including $42 million of secondary impacts (those impacts due to the personal expenditures of workers being paid by the $58 million investment).

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*$18,000 is an estimate of value added in 1974 dollars per job derived by Harbridge House. Value added is defined as the value of finished products less the cost of raw materials.

**This system includes improvements to the level of Plan A, Plan B, or Plan C on most lines and bus service on others, as described in Chapter 6.

To estimate the number of new jobs that will be created by these expenditures it is assumed that commuter rail improvements will generate jobs at a level similar to that of rapid transit construction.*** Approximately 1000 new state-wide jobs would be created from the primary commuter rail investments. Total employment generated (which includes both primary and secondary impacts) in the state is estimated at 2500 jobs. Most of these jobs would exist only during the construction period.

7.3.4 Local Deficit Assessments

Estimates were made of the 1985 deficit that would be assessed to local cities and towns for two scenarios: 1) the previously discussed composite system and 2) a variation of this system which continues rail service for all lines by assuming Plan A improvements on those lines where bus service was specified for the composite system. These estimated assessments are shown in Tables 7-3 and 7-4. Only the assessment due to commuter rail or substitute commuter bus service is included.

As compared to the total 1977 assessed deficit of $10.3 million, the composite system would result in an estimated 1985 assessment of $13.5 million (increase of 31.1%) while the 1985 all rail system results in an $18.8 million assessment (increase of 83%). This compares with an estimated inflation of 69.3% over the same time period. It is important to note than an annual inflation rate of 6.8% was used in calculating the 1985 operating costs and a rate of 4.4% was used for annual fare increases.

Table 7-3 shows the estimated 1985 commuter rail/bus deficit, broken down in terms of how it would likely be paid for, based on continuation of existing policies. As can be seen from the table, the gross deficit is $11.2 million greater for the all rail system than for the composite system; the state's share is $5.3 million greater, and the total assessable to the communities is also $5.3 million greater.

Table 7-4 shows a comparison under each scenario of the 1985 commuter rail/bus deficit which would be assessed against each community, using the totals from Table 7-3 and estimating a distribution of these over the communities on the basis of current assessment formulas and practices. This table shows that because commuter rail deficits are

*** In a study of the impact of Mass Transit Construction on the Massachusetts Economy it was estimated that $1 million (1967 $'s) in transit construction generates 32.5 direct jobs and 46.8 indirect jobs.

	Composite	All Rail
Gross Operating Costs (including debt service)	$46,045,000	$58,566,000
Revenue (including reimbursement from outside comm)	18,501,000	19,817,000
Gross Deficit	27,544,000	38,749,000
Federal Share	2,480,000 *	3,421,000 *
State Share (including debt service)	12,542,000	17,853,000
Net Deficit	12,522,000	17,475,000
State Treasurers Charges	963,000	1,330,000
Total Assessable to Communities	13,485,000	18,805,000
Federal Share of Gross Deficit Plus State Treasurer's Charges	8.7%	8.5%
State Share	44.0%	44.6%
Communities' Share	47.3%	46.9%

* Taken as a constant percentage of deficit. Actual Federal contribution will depend on commuter rail miles according to new Section 5 formula.

ESTIMATED 1985 COMMUTER RAIL DEFICIT - FEDERAL, STATE, AND LOCAL SHARES

TABLE 7-3

Community	Composite	All Rail	Community	Composite	All Rail	Community	Composite	All Rail
Arlington	213	320	Lynn	214	290	Rockland	50	68
Ashland	32	45	Lynnfield	39	55	Salem	115	155
Bedford	38	52	Malden	175	261	Saugus	90	127
Belmont	107	160	Manchester	14	19	Scituate	53	72
Beverly	124	170	Marblehead	73	101	Sharon	53	74
Boston	5,310	7,814	Marshfield	51	66	Sherborn	12	16
Braintree	114	156	Maynard	31	43	Somerville	325	488
Brookline	303	455	Medfield	29	40	Stoneham	79	109
Burlington	72	97	Medford	227	341	Sudbury	46	62
Cambridge	587	874	Melrose	133	178	Swampscott	56	78
Canton	63	87	Middleton	14	19	Topsfield	18	24
Chelsea	87	130	Millis	18	25	Wakefield	89	127
Cohasset	22	29	Milton	117	175	Walpole	59	81
Concord	167	65	Nahant	17	25	Waltham	200	204
Danvers	80	111	Natick	134	135	Watertown	140	209
Dedham	95	132	Needham	134	142	Wayland	47	65
Dover	17	22	Newton	345	516	Wellesley	214	120
Duxbury	23	29	Norfolk	15	20	Wenham	13	18
Everett	144	216	No. Reading	44	62	Weston	36	51
Framingham	213	248	Norwell	29	41	Westwood	50	70
Hamilton	26	36	Norwood	106	146	Weymouth	202	280
Hanover	34	47	Peabody	157	219	Wilmington	56	77
Hingham	57	78	Pembroke	40	56	Winchester	84	118
Holbrook	44	62	Quincy	420	594	Winthrop	79	111
Hull	33	44	Randolph	101	140	Woburn	128	179
Lexington	110	153	Reading	105	124			
Lincoln	86	46	Revere	208	311	TOTAL	13,485	18,805

TABLE 7-4

ESTIMATED 1985 COMMUTER RAIL/BUS ASSESSMENTS - BY COMMUNITY

($ THOUSANDS)

assessed according to the "express" formula, which includes population as well as commuter rail and rapid transit boardings, a significant part of the commuter rail deficit falls upon the inner cities and towns. Thus they would share in the benefit of the lower assessments of the composite system. Generally, the assessments of the composite system are lower than the assessments of the all rail system. The three exceptions are for Concord, Lincoln, and Wellesley, each of which would receive bus service in the composite system. Bus deficits (including express buses) are assessed according to the "local" formula and fall more heavily on the community where the service is provided. (Table 7-3 should not be interpreted to signify how much each individual community's total assessment would increase or decrease under either system as compared to no suburban commuter service. Such a calculation would have to take into account in addition the distribution of the rapid transit deficit and the remainder of the bus deficit, each of which would change somewhat under the composite system.)

7.4 CONSIDERATION OF SPECIAL MOBILITY PROBLEMS

On June 8, 1978, the U.S. Department of Transportation proposed some far-reaching regulations relating to the treatment of handicapped persons in federally-assisted programs. Even though these regulations are not yet final, some plans have already been made to provide changes in commuter rail station design and vehicle specifications to accommodate the handicapped.

Significant barriers to use of a public bus or rail vehicle for those with mobility problems include (1) the movement of the vehicle, (2) gaining access to the vehicle from ground level, and (3) movement in crowds. Therefore, structural alterations must be undertaken not only to provide access but also stability for those in wheelchairs and for other individuals who have difficulty negotiating steps. In addition, there are certain features, such as lighting and door closing signals, which could be added to vehicles, thereby enhancing their safety.

7.4.1 Commuter Rail

The entire commuter rail system has low platform stations. Both coaches and Budd cars have four steps leading to a floor about 51 to 52 inches above the rail, and minimum aisle widths of 25 to 26 inches. Commuter rail vehicles do not have floor space or aisle widths for a wheelchair. Included in the proposed improvements for the commuter rail system are certain features designed to make both stations and vehicles more accessible to the handicapped. Work contracted for some of the existing stations includes ramps, and platforms which would be no lower than eight to nine inches below the first train step.

Plans for the Boston CBD stations include high platforms at South Station and a fully accessible Back Bay Station with both elevators and escalators. All new coaches will have lower steps and a slightly lower floor height than old equipment. Both door-width and aisle-width will be 30 inches, which provides enough space for a wheelchair. Seating changes have also been planned which would provide adequate space for wheelchairs at one end of the vehicles. Numerous other safety features have been incorporated into the design of the vehicles, such as handrails in the vestibule and increased levels of lighting.

All of these features will make the new equipment more accessible to the handicapped. There is no basic cost difference between this type of vehicle and a standard vehicle. However, problems will still remain in a majority of the commuter rail stations for getting a wheelchair user from station-platform to vehicle floor level.

7.4.2 Buses

All of the standard buses have a floor height of about 34 inches, and the first step varies in height from about 12 to 14 inches. They have a minimum aisle width of 30 inches and a rear door width of 30 to 42 inches. Available floorspace is not adequate for wheelchairs. All buses have handrails/stanchions and non-slip floor/step coverings. Acquiring new buses which have such features as a wheelchair lift, folding seets and/or wheelchair tie-downs would require an expenditure of between $9,000 and $12,000 above the present cost of a new bus.

The interior specifications of new buses and commuter rail coaches can accommodate the needs of individuals with mobility problems. A more difficult problem remaining is that of providing easy access from platform to vehicle floor level. New buses acquired under the composite system could have features remedying the problem of steps. The adaption of old rail vehicles remaining in commuter service would require extensive structural alterations. New coaches would also require design changes, such as the addition of lifts to be fully accessible to the handicapped. Federal regulations will ultimately determine in large part the system changes which will be installed to meet the needs of individuals with special mobility problems.

8.0 RECOMMENDATIONS AND IMPLEMENTATION

As stated in Chapter 1, the objective of this study has been to determine whether the Commuter Rail Improvement Program (CRIP) should be continued, and, if so, in what form. The study has shown that commuter rail is the only viable public transportation service in many corridors throughout the region. Hence, it seems clear that CRIP should continue.

This chapter is oriented towards determining the form that continued program should take, and further, what steps need to be taken to get there. Recommendations are made as to the status of each line. Service experiments are recommended to confirm or refute the results of this analysis in each case where conversion to commuter bus seems most cost-effective. Lastly, the likely next steps in the evolution of the MBTA's commuter rail system are described in the context of the agencies and other groups which will be involved in that evolutionary process.

8.1 SUMMARY OF RECOMMENDATIONS

The capital requirements, the ridership response and the operating costs of stabilizing and improving commuter rail service, and the practical possibilities of offering a viable substitute bus service vary greatly among the commuter rail lines. Though certain costs are fixed for the entire system and do not change if service on a given line is changed, it is important to review each line individually as well as to look at the system as a whole.

In summary, there is no viable alternative to improved commuter rail service on at least four routes. On other routes, commuter bus service appears to be more cost-effective, but in varying degrees. While this suggests which routes should receive priority for investment, it does not necessarily provide a decisive argument for discontinuance of any one line.

Also, commuter rail ridership may respond even better than anticipated to improved service. Only within the next two years will the MBTA acquire a reasonable-sized fleet (yet still not enough to replace some of the in-use, out-dated equipment) of new coaches and reliable

locomotive power. Even though the effect of reliability of new equipment can be predicted, it is difficult to quantify fully the effects of comfort and simple amenities on ridership. In addition, there may be cost-reduction schemes such as work rule changes[1], or cost-sharing, such as service contracts with outside RTA's (described in Section 8.3), which could also change the cost-effectiveness of any line.

Thus the investment strategy and operating strategy suggested by this analysis is one of concentrating substantial investment on four routes in order to stabilize service and subsequently to make substantial additional improvements on some of those routes. Under this strategy, the other routes would only receive the investment required to maintain service or to support service experiments. Some of what would be entailed in these service experiments is described in Section 8.3. Again, each line must be considered individually.

8.2 FINDINGS AND RECOMMENDATIONS, BY LINE

* Eastern Route to Ipswich

  Findings: Commuter rail provides the only viable means of offering good public transportation for the North Shore suburbs beyond Lynn, despite high capital requirements. Significant increases in ridership are possible through the development of improved frequency and reliability. A station at or near Route 128 could attract significant patronage and relieve pressure for parking at the downtown Beverly station. However, it may be difficult to develop such a station due to recent land development and congestion on access roads.

  Recommendations: Begin making permanent improvements to restore the right-of-way and stabilize service, as in Plan B. If the Blue Line is extended to Lynn, undertake no additional improvements. If it is not, improve to the Plan C level. Undertake program to expand parking facilities where demand warrants, especially in Beverly.

1. These have not been explored in this study.

* Gloucester Branch

Findings: Significant capital investment is required to keep the branch in service. Net cost of service per trip is three times as high as any other line. Most of the riders on the branch could be attracted to commuter rail if a station with adequate parking were easily accessible from Route 128.

Recommendations: Proceed with only essential, safety-related investments. Convert to one-track to minimize capital requirements. Proceed immediately with plans to develop station facilities accessible from Route 128.

* Reading Line

Findings: A good bus service can be offered at near break-even level while retaining a large percentage of the existing rail ridership. Operation of commuter rail is much more expensive than bus, though high capital investment is not required. Ridership on the rail line continues to decline due to competition from I-93 and the Orange Line (ridership in 1977 was only 65% of ridership in 1974).

Recommendations:
Monitor ridership with more reliable equipment. Develop service experiments to evaluate potential (see Section 8.3). Make no investment in right of way except for investment that might be needed to maintain service during the experiment period. Include either level of service changes or service extensions, or both. Incorporate into MBTA bus purchase program enough slack to have buses available should more reliable rail service not prove successful.

* New Hampshire Division

Findings: Commuter rail provides a good service; bus service performs poorly by the evaluation measures employed.

Recommendations: Restore right-of-way to Plan B level and stabilize service. Experiment with higher frequency service (up to Plan C).

* Fitchburg Route

Findings: There is no potential for a viable bus service until Alewife Station on the Red Line is in operation. At that time, analysis indicates that a more cost-effective bus service could be provided into Alewife.

Recommendations: Retain service until Alewife Station is in operation and at that time reassess the potential for bus service. Develop service experiments to evaluate potential (see Section 8.3). Include either level of service changes or service extensions, or both. Limit capital investment to that which is necessary to maintain service until final decision is made.

* Framingham (B&A) Line

  Findings: A viable bus service can be offered at lower cost. However, very little MBTA capital investment is required to maintain commuter rail service.

  Recommendations: On this line, service experiments might include off-peak service. Make no capital investments in the line until experimental results are clear. Develop service experiments to evaluate potential (see Section 8.3). Include either level of service changes, or service extensions, or both.

* Needham Branch

  Findings: A viable bus service can be offered at considerably lower cost. The temporary discontinuance of commuter rail service in connection with Southwest Corridor construction offers an opportunity to judge whether such a bus service can succeed in the long run.

  Recommendations: Proceed with bus service during Southwest Corridor construction. Evaluate effectiveness of bus service after two years and reassess. Make no investment in rail right-of-way in the interim.

* Franklin Branch

  Findings: Commuter rail provides a good service with no viable potential bus alternative. Considerable improvements already made in right-of-way.

  Recommendations: Complete restoration of right-of-way to Plan B level. Improve service levels where feasible, and where ridership response warrants.

* Shore Line

  Findings: Commuter rail provides good service with no viable bus alternative. Major commitment to right-of-way by Federal government for Northeast Corridor service.

Recommendations: Upgrade service as right-of-way is upgraded in connection with Northeast Corridor Project. Develop expanded parking facilities where demand warrants.

8.3 SERVICE EXPERIMENTS

It is clear that there is no viable alternative to improved commuter rail service on at least four routes. On the other routes, commuter bus service appears to be more cost-effective. However, before conversion to commuter bus can become public policy in these corridors, the effects of new equipment and improved service on the cost-effectiveness of rail service must be evaluated. This evaluation should occur through the development of a series of service experiments which are carefully monitored for their impacts on ridership and cost-effectiveness.

An important part of the evaluation is the development of criteria for measuring the success or failure of the experiments. In other words, before experiments begin, a decision-rule must be defined which clarifies how much ridership and/or cost-effectiveness must improve for commuter rail to be retained on any line being tested.

Service experiments could be of two types: level of service changes, or service extensions, when costs can be shared with another regional transit authority (RTA). It is also conceivable that these two changes could be implemented together in one experiment.

While service experiments should become part of a continuing commuter rail plan refinement process, they are beyond the scope of this study. However, outlined below is a framework in which those tests should be developed and evaluated.

8.3.1 Level-of-Service Changes

The level of service presently offered carries a group of tenacious commuter rail patrons on aged equipment that the MBTA purchased from the Penn Central and the B&M. In addition, there are other patrons whose use of rail is less committed. If service decreases, or fares go up, they are likely to switch to their cars or commuter bus if it is available. As new equipment arrives at the MBTA, opportunities exist to retain more of these less committed patrons, and attract new patrons to the system. These opportunities arise due to the increased reliability of new equipment, the provision of minimum passenger amenities (which have often been lacking), and the feasibility of improved service.

Each of these three aspects of new equipment should be exploited in the framework of a test to confirm or refute the conclusions of this study. MBTA and CTPS should cooperate in developing and implementing these tests. The tests, if designed properly, should determine whether rail lines which perform poorly in comparison to bus can be improved to a level which would change the results of this study.

The level of improvement required is an open question which would need to be resolved before the tests begin. The evaluation criteria used in this study may be used as guidelines, and improvements may be measured in terms of percentage increase (or decrease) of any of the existing measures. For example, the required level of improvement may be defined in a manner such as: "When an improved service (offerred in these service experiments) results in a cost-effectiveness (as measured by net cost of service per rider) within 10% of the cost-effectiveness of the proposed commuter bus service". Other criteria might also be developed.

Included in the tests would be improved reliability, increased frequency, express service, and skip-stop operation. The individual effects of each of these factors have been tested before, most notably in the 1963 MTC experiments. Therefore, the service experiments suggested here should be designed to obtain the maximum effect within a market area. This means that a test on any line should entail the operation of "optimal" service which may require 2 or 3 iterations during semi-annual schedule changes.

Along with the improved service, an aggressive marketing campaign should be run. This is necessary to show the public that a fast, inexpensive, convenient, comfortable alternative service is available. Without a marketing campaign, dramatic improvements in cost-effectiveness are much less likely, and hence any test which "fails" will be tainted by the fact that only a partial effort to achieve success was attempted.

Service experiments will result in increased costs to the MBTA, both due to the increased frequencies that will be likely, and due to the marketing campaign that will be necessary. The increased frequencies will require that additional equipment be available. Initially there are two lines on which some form of tests should be conducted--the Framingham and the Reading. A probable <u>upper limit</u> on the budgetary impact of such tests has been calculated by assuming that the number of trains per day on these

lines would be approximately doubled. If such a test were conducted for two years on both lines simultaneously, then the operating costs would increase by about $500,000 in 1977 costs. If new equipment were purchased for the tests, it would require $4,400,000 in capital costs for equipment, which can be assumed to be leased for about $440,000 per year. Allowing for some inflation, the total annual cost would come to about $1.2 million. This added operating cost would be offset by additional revenue. If ridership were to increase 20% during the test, it would bring in about $340,000. A 50% increase would bring in $850,000. Thus, if another $150,000 were allowed for promotion and monitoring, the annual deficit would probably increase by $500,000 to $1,000,000 during the period of experimentation on those two lines. If ridership were to respond still more positively, then the experiments would come closer to breaking even.

All of the above comments also apply to the Needham Branch, where bus service will be tested instead of commuter rail. That is, ridership and costs should be monitored closeby and the new service should be marketed, in order to determine if the results would be any different than predicted here.

There are several possible sources of funds for service experiments. The experiments could be handled exactly as the rest of the commuter rail deficit--that is, half could be paid by the Commonwealth and half by the cities and towns, or there could be a special arrangement for placing a somewhat heavier burden on the Commonwealth. Alternatively, Federal funds in the form of UMTA demonstration monies could be sought in order to offset the cost of some portions of the experiment which may be of particular interest to UMTA.

8.3.2 Service Extensions

The MBTA is presently negotiating with Merrimack Valley Regional Transit Authority (Lawrence/Haverhill) and the Montachusett Regional Transit Authority (Fitchburg/Gardener) to operate extensions of service to these areas. Trains did run to these areas in the recent past*, but due to the reluctance of individual communities to pay for the service, it was cancelled. The formation of Regional Transit Authorities (RTAs) in these areas, and the availability of Federal funds to assist with operating costs and capital costs has reopened the possibility of running these services.

Extensions of service to these RTAs or to others could have positive impacts on the cost-effectiveness of any line. This improvement could result from the sharing of costs, minimi-

*Service to Lawrence and Haverhill was terminated in July 1976, and service to Fitchburg was terminated in January 1965. Service to Ayer on the line to Fitchburg was terminated in March 1975.

zation of non-productive deadheading, as well as an increase in ridership. Also, patrons at new stations would pay greater fares.

Extensions have not been evaluated under the scope of this study. Service extensions on lines whose future is called into question by this report need to be evaluated in a manner very similar to the one outlined in the previous section. Evenmore, it is likely that a service extension and improved service on inner portions of a line could occur together, and thereby provide an optimal environment for any line. If a line's cost-effectiveness did not improve markedly with both of these changes, then there would be little reason not to substitute bus service. It may be that in order to provide well run service extensions some limited capital investments in the existing plant will be required. These investments should be kept to a minimum, and further should be concentrated on equipment, or other types of investments that will serve a continuing function whether or not a line remained in service.

8.4 Next Steps

The study was designed to provide a thorough technical analysis of commuter rail and alternatives thereto. This report is not in and of itself a statement of policy. The acceptance of the report's recommendations and the development of a policy is a process which will occur over at least the next several months and may not be resolved for several years.

It is a process involving a number of agencies and legislative bodies at different levels of government and a number of citizen organizations and interest groups. Since the process is not a well defined one, it is only possible at this stage to outline the role which each group is likely to play in this process.

8.4.1 MBTA

The MBTA is involved in implementing the recommendations of this report in a number of ways, and they are likely to perform various tasks in the process of developing a policy towards commuter rail.

First, the publication of this report means simply that the report fulfills the contractual obligations of CTPS, and that the information presented is complete and meets the MBTA's objectives for the study. It does not, however, imply that the MBTA has necessarily accepted the recommendations of the study.

The second involvement of the MBTA will occur through preparation and submission to UMTA of further CRIP Capital Grant applications. As these grants are prepared, the MBTA must decide whether the capital priorities will be guided by the results of this study, or whether some modifications are needed.

A third manner in which the MBTA could formulate policy would be to state a new policy towards commuter rail. This would occur in cooperation with EOTC (the state's Executive Office of Transportation and Construction), inasmuch as EOTC has been designated by the legislature as the agent for preparation of MBTA long-range plans and programs. A public review process, which has in effect already begun, would be built into the development of such a policy statement.

The MBTA must also decide whether to implement service experiments for certain lines as recommended in this report, and then must design these experiments in some detail, in the context of regular commuter rail service on the system as a whole. Finally, after these experiments are conducted and the results evaluated, the MBTA must decide what type of service to offer in each corridor. The latter decision would therefore take several years, assuming the experiments are conducted.

8.4.2 EOTC

As stated above, EOTC plays a key role in the preparation of MBTA long-range plans and programs. The Program for Mass Transportation (PMT) is the primary EOTC document in this process, but other major MBTA planning documents also must receive EOTC review and approval. In this way, EOTC is critical in development of transit policies. The CRIP Plan Refinement Study Report is one such document which will require EOTC review.

8.4.3 MBTA Advisory Board

The Advisory Board's role in the development of policy will manifest itself in two ways. First the Advisory Board reviews the MBTA budget and may approve or disapprove it in whole or in part. Thus the Advisory Board may make changes in the commuter rail budget proposed by the MBTA in future years including proposed increases in service or bus substitution, and could influence the nature of the service in that way. Second, the Advisory Board must also review and approve the Program for Mass Transportation (the long range plan for transit service) and could influence the long term plan for commuter rail in that manner.

8.4.4 General Court

The General Court (Massachusetts Legislature) plays an important role in policy toward commuter rail because of the necessity of legislative appropriations to sustain MBTA operations and because of the legislative authority needed to float additional bonds to pay the 20% share of capital expenses. Though the Legislature will normally allow considerable latitude to the MBTA in its operation and capital investment, it can in each instance impose restrictions requiring or limiting specific expenditures in commuter rail. Individual legislators will undoubtedly be concerned about the nature of service to the areas which they represent.

8.4.5 JRTC

In the Boston region, the Joint Regional Transportation Committee (JRTC) has been officially designated as the transportation policy advisory group. This means that it reviews policy documents for the region and makes recommendations for implementation or revision. After the Draft of this report was released for public review, JRTC became involved in that review process.

On September 20, 1978, the Plan Refinement Study Report was presented to the JRTC. This presentation included description of the analyses performed and of the recommendations made. At that meeting, JRTC decided to form a special advisory committee to review the report. At the present time, the advisory committee's efforts are underway, and it is expected that they will make recommendations in the form of their own report to the full JRTC by mid-February. The JRTC at that time may want to make recommendations to MBTA/EOTC on the CTPS report.

8.4.6 City and Town Officials

In addition to their capacity to act collectively through the MBTA Advisory Board, city and town officials, particularly in suburban areas, will be concerned with the type of service which their individual area would receive under a new policy toward commuter rail. This will be particularly true in areas where there is a potential for substitution of bus service after the period of service experiments. Thus, officials of individual municipalities will insist on a detailed scrutiny of possible changes affecting them and will want a thorough documentation of the reasons for any permanent changes in service.

8.4.7 Urban Mass Transportation Administration

UMTA, which has the authority to approve capital and operating grants for public transportation, has not traditionally

involved itself in the regional allocation of service or in details about the level of service to be offered. However, in areas where substantial expenditures of Federal funds are made, UMTA has required assurances that the alternative chosen represents an efficient expenditure of Federal funds for meeting local transportation, land use and other objectives. The need for these assurances has been one of the principal reasons for undertaking the CRIP Plan Refinement Study. Thus UMTA will probably view this report as an important guideline for future investment of Federal funds in commuter rail.

LIST OF REFERENCES

The following is a list of reports and planning documents which refer to the Boston commuter rail system. It includes selected documents produced by agencies and the state legislature and lists them in chronological order.

1926

Massachusetts Division of Metropolitan Planning, Report on Improved Transportation Facilities in the Boston Metropolitan District, December 1926.

1945

The Commonwealth of Massachusetts, Report of the Special Commission to Investigate Railroad Transportation Facilities within the Commonwealth, January 1945.

The Commonwealth of Massachusetts, Report of the Metropolitan Transit Recess Commission, April 1945.

1947

The Commonwealth of Massachusetts, Report of the Metropolitan Transit Recess Commission, April 1947.

1948

The Commonwealth of Massachusetts, Special Commission Relative to the Continuation of Transportation Service in the Areas served by the Old Colony Division of the New York, New Haven and Hartford Railroad Company and in Martha's Vineyard and Nantucket: Third Interim Report, June 1948.

The Commonwealth of Massachusetts, Special Commission Relative to Continuation of Transportation Service in the Areas served by the Old Colony Division of the New York, New Haven and Hartford Railroad Company and in Martha's Vineyard and Nantucket: Fourth Interim Report, December 1948.

1958

The Commonwealth of Massachusetts, *Report of the Metropolitan Boston Transportation Commission*, January 1958.

The Commonwealth of Massachusetts, *Final Report of the Special Commission to Investigate and Study the Continuation of Freight and Passenger Service by the New York, New Haven and Hartford Railroad Company, The Boston & Maine Comapny and The Boston and Albany Railroad*, January, 1958.

1959

Old Colony Area Transportation Commission, *First Report Relative to the Old Colony Commuter Problem*, January 1959.

Old Colony Area Transportation Commission, Second Report Relative to the Old Colony Commuter Problem, April 1959.

Deleuw, Cather, Inc., *Report to the Old Colony Area Transportation Commission on Plans for Improved Suburban Transit*, April 1959.

Boston College Seminar Research Bureau, *Problems of the Railroads*, June 1959.

1961

The Commonwealth of Massachusetts, *An Act Establishing the South Shore Transportation District*, Implementing the Exercise of the Option to Purchase Part of the Former Old Colony Railroad Right-of-Way and Providing for Rapid Transit Passenger Transportation Between the Town of Braintree and the City of Boston, 1961.

Boston and Western Suburbs Transportation Council, *Rail Commutation Service West of Boston*, February 1961.

The Commonwealth of Massachusetts, *Special Report to the Massachusetts Transportation Commission Relative to the Discontinuation or Curtailment of Service by Railroads*, The Control and Maintenance of Grade Crossings and other Related Matters, 1961.

The Commonwealth of Massachusetts, *An Act to Complete the Exercise of the Option to Purchase the Boston-Braintree Segment of the Old Colony Railroad and to Provide for the Creation of the South Shore and Cape Cod Transportation District*, 1961.

The Commonwealth of Massachusetts, An Act Providing Tax Relief for Certain Railroads Doing Business in the Commonwealth and Meeting certain Established Standards of Service, 1961.

1962

Prepared for the Mass Transportation Commission by the Planning Services Group, The Boston Regional Survey Transportation Inventory, chap. 5, Public Transportation, 1962.

Prepared for the Mass Transportation Commission by the Planning Services Group, The Boston Regional Survey Transportation Inventory, chap. 6, Railroads, 1962.

The Commonwealth of Massachusetts, Report of the Joint legislative Recess Committee on Transportation to the General Court on Railroads, Private Bus Companies and Special Transportation Districts, 1962.

Mass Transportation Commission, Summary of the Report to the General Court on the Engineering Feasibility of an Extension of Rapid Transit Service (from Sullivan Square in Boston to Route 128 in Reading) Along the Boston & Maine Railroad Right-of-Way, 1962.

1964

Prepared for the Mass Transportation Commission by Systems Analysis and Research Corporation, Old Colony Busway Study, February 1964.

Prepared for the Mass Transportation Commission, Mass Transportation in Massachusetts; final Report on a Mass Transportation Demonstration Project, July 1964.

Deleuw, Cather, Inc., Proposed Extension of Main Line Rapid Transit Facilities over the New York, New Haven and Hartford Railroad from Washington Street Tunnel to Route 128 in Dedham, Prepared for the MTA, July 1964.

Agreement between Massachusetts Bay Transportation Authority and the Boston and Maine Corporation for the Provision of Passenger Train Service within the Commonwealth of Massachusetts, December 1964.

1965

Massachusetts Bay Transportation Authority and Richard Joyce Smith, William J. Kirk and Harry W. Dorigan, Trustees of the Property of the New York, New Haven and Hartford Railroad Company, Agreement for the Provision of Passenger Train Service and the Sale or Option of Certain Real Estate within the Commonwealth of Massachusetts, July 1965.

1966

MBTA, Comprehensive Development Program for Public Transportation in the Massachusetts Bay Area, May 1966.

MBTA, The Program for Massachusetts Transportation: A Program for Improving Massachusetts Transportation Facilities in the Area Constituting the Authority, August 1966.

MBTA, Staff Supplementary Report to the Program for Massachusetts Transportation of the Massachusetts Bay Transportation Authority, August 1966.

1967

MBTA, Report on Extension of Commuter Railroad Financing, January 1967.

MBTA, Marketing Conditions and Supporting Data Related to the Commuter Rail Contract Service, January 1967.

1969

MBTA, Report on Alternative Programs for Suburban Commuter Service, January 1969.

The Commonwealth of Massachusetts, Special Commission Relative to the Finances and Operation of the MBTA: Interim Report on the Commuter Railroads, July 1969.

1972

Thomas K. Dyer, Inc., Plan for Acquisition and Use of Railroad Rights-of-Way (Prepared for the MBTA), 1972.

1973

MBTA, Preliminary Report Commuter Rail Improvement Program, 1973.

Boston Transportation Planning Review, Final Study Summary Report, February 1973

1974

Massachusetts Executive Office of Transportation and Construction and the MBTA, Ten Year Transit Development Program 1974-1983, June 1974.

1975

Massachusetts Executive Office of Transportation and Construction with the Assistance of the Central Transportation Planning Staff, Five Year Transit Development Program Boston Region 1975-1980, June 25, 1975.

Prepared for the Massachusetts Department of Public Works and the United States Federal Highway Administration, Statewide Railroad Right-of-Way Study, June 1975.

Massachusetts Executive Office of Transportation and Construction, Massachusetts State Rail Plan, December 1975.

MBTA, Application of the MBTA for a Massachusetts Transportation Capital Improvement Grant for a Commuter Rail Improvement Program (Phase I), January 14, 1975.

1976

MBTA, Application of the MBTA for a Massachusetts Transportation Capital Improvement Grant and an Advance Land Acquisition Loan for a Commuter Rail Improvement Program (Phase II), May 1976.

Central Transportation Planning Staff, Transportation Improvement Program for the Boston Region 1976-1980 Including an Annual Element (Prepared for the Metropolitan Planning Organization), June 1976.

Massachusetts Executive Office of Transportation and Construction, Program for Commuter Rail Improvement, August 1976.

MBTA, Final Application of the MBTA for an Emergency Operating Subsidy Grant for the Continuation of Commuter Railroad Service, October 1976.

1977

Metropolitan Area Planning Council, Staff Review of the Program for Commuter Rail Improvement, February 1977.

Central Transportation Planning Staff, Commuter Rail Improvement Program Plan Refinement Study Overview Report (Prepared for Submission to the Technical Coordinating Committee of the Plan Refinement Study), March 1977.

Massachusetts Executive Office of Transportation and Construction, 1977 Revised Program for Massachusetts Transportation, April 1977.

Skidmore, Owings & Merrill, Commuter Rail Improvement Program Immediate Action Report Station Development Study, June 1977.

Massachusetts Executive Office of Transportation and Construction, Massachusetts State Rail Plan 1977, August 1977.

CTPS, Transportation Improvement Program for the Boston Region (Prepared for the MPO), September 1977.

DeLeuw, Cather Inc., Commuter Rail Improvement Program Maintenance Facilities Phase A. (Prepared for the MBTA), October 1977. (Draft)

1978

CTPS, Commuter Rail Improvement Program Plan Refinement Study Final Report (Prepared for the MBTA), August 1978. (Draft)

MBTA, Preliminary Application of the MBTA for a Mass Transportation Capital Improvement Grant for a Commuter Rail Improvement Program (Phase III), August 1978.

Massachusetts Executive Office of Transportation and Construction, Massachusetts State Rail Plan 1978, August 1978

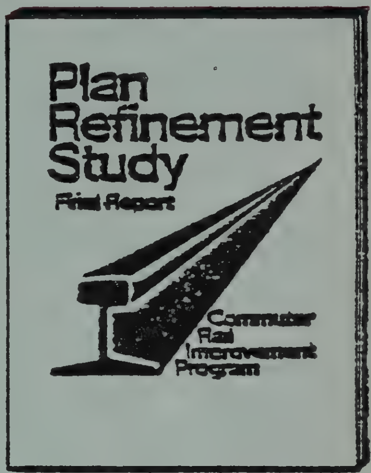
CTPS, Transportation Improvement Program for the Boston Region (Prepared for the MPO), September 1978.

Massachusetts Executive Office of Transportation and Construction, 1978 Revised Program for Mass Transportation, November 1978.

Plan Refinement Study

Commuter Rail Improvement Program

TECHNICAL APPENDICES



A.1 Analysis of operating costs of Commuter Rail Service alternatives

A.2 Analysis and forecasting of ridership for Commuter Rail Service alternatives

A.3 Description of Commuter Bus alternative

May 1979

TECHNICAL APPENDIX A.1

TITLE ANALYSIS OF OPERATING COSTS OF COMMUTER RAIL SERVICE ALTERNATIVES

AUTHOR(S) ALICIA WILSON, HAMID AMINIAN, THOMAS HUMPHREY

DATE MARCH 1979

ABSTRACT This appendix documents the calculation of operating and capital costs for the Base Case commuter rail, three rail alternatives, and a bus replacement system.

Included in this appendix are: a description of present rail system costs, alternative rail plan costs, and the costs for the bus replacement service.

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CENTRAL TRANSPORTATION PLANNING STAFF 27 School Street, Boston, Mass. A Cooperative Planning Effort of MAPC, EOTC, MDPW, MBTA, MBTA ADV. BD., MASSPORT.

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1.0 INTRODUCTION

The purpose of this appendix is to document the calculation of operating and capital costs for the Base Case commuter rail system, three rail alternatives and a bus replacement system. It should be noted that all costs were calculated in constant 1977 dollars.

This appendix includes description of present rail system costs, alternative rail plan costs, and the bus replacement service costs.

1.1 DATA SOURCES

The major sources of information for the Base Case analysis were the MBTA Commuter Rail Department (Run Book #21, Supplement #12, which lists the assignment of train crew by line), fall 1977 train schedules, the back-up data for the B&M monthly commuter service expenditure reports, and the 1978 MBTA budget. A discussion of the reasons for using the two latter data sources follows.

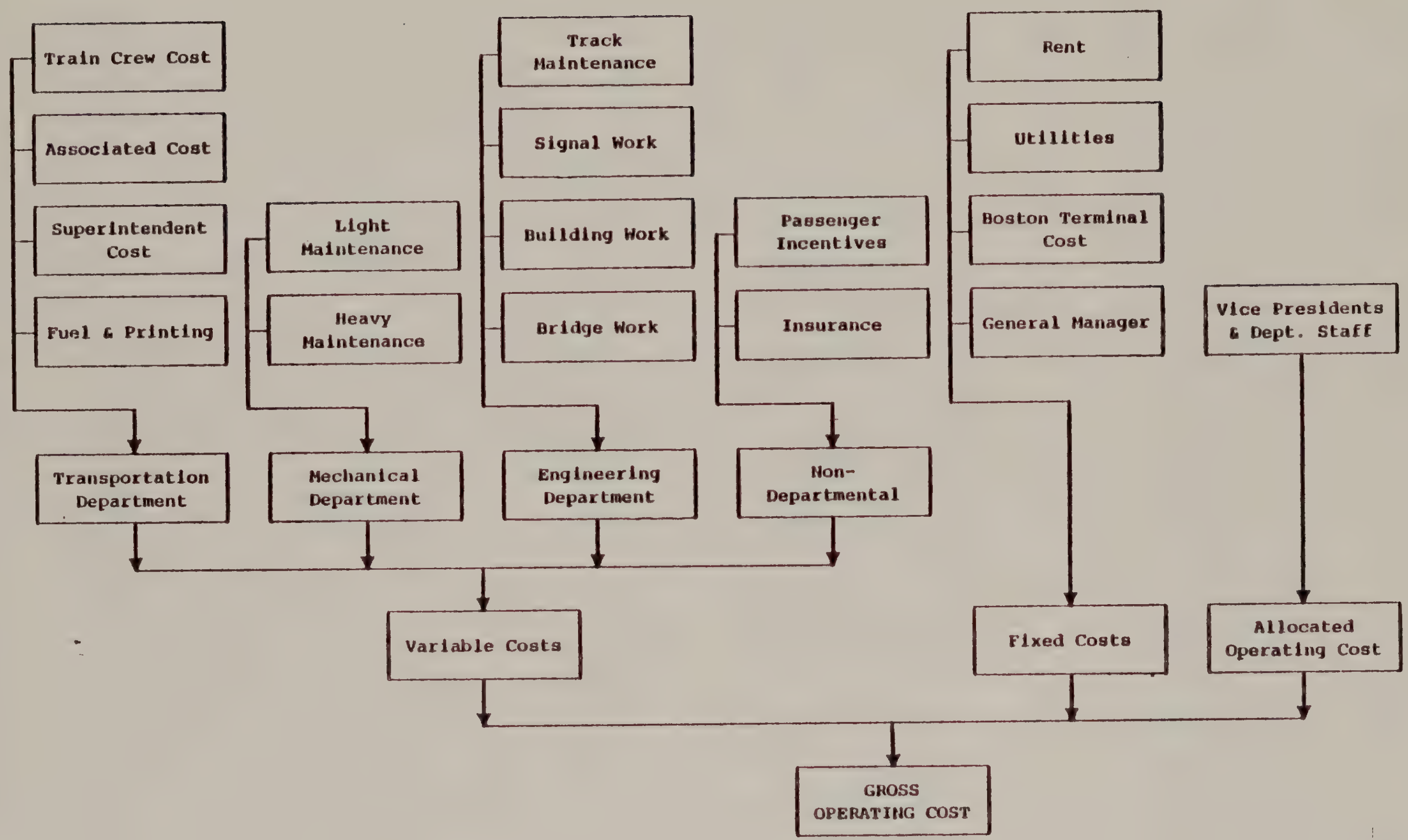
The B&M provides the MBTA with a report of commuter rail expenditures for each month of service on the Northside. These reports itemize departmental costs to some degree; however, they were not detailed enough for purposes of this study. For example, neither fixed costs nor line-specific (direct) costs could be determined from these reports. Therefore, the B&M back-up data had to be used to estimate the present gross operating costs of Northside service. The data were itemized by category in three general areas--specific, overhead and indirect costs--and for nine departments, including accounting, executive, engineering and mechanical. At the time analysis of costs began, these data were available for the first eight months of service only. Therefore they were annualized to estimate costs for a full year of service. In most instances the costs were averaged for eight months and multiplied by twelve. However, in some cases engineering costs for the months of July and August didn't reflect the total amount expended because a substantial share of work and material were paid for with capital funds. (Only expenses paid for out of the operating budget are included in the back-up data.) In these cases, costs for the first six months of service were averaged and

multiplied by twelve. The Transportation Department accounts for 41 percent of total gross costs, the Mechanical Department for 32 percent, and the Engineering Department for 17 percent.

The determination of Base Case operating costs for Southside service was more difficult since the B&M did not begin to provide service on these lines until the spring of 1977. As a result, the data base was not adequate to estimate operating costs for the entire year. Therefore, upon the suggestion of the MBTA's Budget Office, 1977 (Base Case) costs were estimated by working backwards from 1978 budget figures. The MBTA's estimated 1978 total gross commuter rail operating costs were 13.5 percent higher than their estimated 1977 total gross costs, so all 1978 budget items were reduced accordingly. The resulting data were not as detailed as those for the Northside, but they were the best that could be obtained at that time. The Transportation Department accounts for 47 percent of total gross costs, the Mechanical Department for 35 percent, and the Engineering Department for seven percent, on the Southside.

1.2 PROCEDURES USED IN CALCULATING THE COSTS

The gross operating cost of the present commuter rail system or the alternative rail plans can be categorized as variable, fixed, and allocated overhead costs. Three departments--Transportation, Mechanical and Engineering--account for the major portion of variable costs, which can be attributed to the operation of service on each of the individual lines. Fixed costs are mostly those costs associated with facilities and areas that would have to be maintained regardless of the total number of rail lines or routes in service at any given time. The remaining costs are not directly attributable to the service on any line, but vary with the amount of service offered, and therefore are allocated on a line-by-line basis according to a set of indices as shown in the flow chart in Figure 1-1.



CALCULATION OF GROSS OPERATING COSTS

FIGURE 1-1

2.0 PRESENT SYSTEM (BASE CASE) COSTS

As mentioned in Section 1.2, the determination of Base Case operating costs had to be handled differently with the Northside and the Southside rail systems because two different companies operated these systems. Description of costs for each system (for the Base Case) follows.

2.1 NORTHSIDE COSTS

2.1.1 Transportation Department Costs

Transportation costs are basically the operational costs for the system. The major variable and line-specific costs are labor costs for train crews (engineers, conductors and trainmen); switchtenders, bridgetenders, at-grade crossing tenders and herders (associated costs); train and crew dispatchers and time keepers (superintendence costs); as well as fuel and printing costs.

Run Book #21, which lists the assignment of crews by train and route, was used to determine train crew costs. The number of hours on duty and the number of miles operated on weekdays, weekends and holidays were determined for each crewman. Crews can be on duty for a maximum of thirteen hours per day. If there is a four-hour break, all time after the ninth hour is considered as overtime. If there isn't a four-hour break, all time after the eighth hour on duty is overtime. Engineers receive extra pay for more than 100 miles of service (overmiles), and conductors and trainmen receive extra pay for more than 150 miles of service. (The rules for crew assignments are as follows: one conductor per train and one trainman for every even car; i.e., a two-car train has one trainman, a three-car train has one trainman, a four-car train has two trainmen, etc.) Pay scales effective July 1977 (see Table 2-1) were used to determine base costs. Fringe benefits, travel expenses and the cost of reserve engineers were added through the use of a factor of 42 percent of direct labor.

During 1977, train service on the Northside was operated entirely by Budd self-propelled Rail Diesel Cars ("RDC's"). Most of these cars have two diesel engines

COMMUTER RAIL

CREW COSTS	NORTH Engineers	NORTH Conductors	NORTH Trainmen	SOUTH Engineers	SOUTH Conductors	SOUTH Trainmen
Base Wage:	$58.56/dy	$79.24/dy	$73.18/dy	$58.56/dy	$74.22/dy	$67.46/dy
Overhours:	$6.83/hr	$6.92/hr	$6.33/hr	$6.83/hr	$6.92/hr	$6.33/hr
Overmiles:	$0.483/mi	$0.3271/mi	$0.3019/mi	$0.483/mi	$0.3271/mi	$0.3019/mi

FUEL COSTS: $0.31/RDC Mile
$0.90/Loco Mile

MAINTENANCE COSTS: $79,000/old RDC
$18,000/old coach
$87,000/old locomotive
$24,500/new coach
$49,500/new locomotive
$56,000/rebuilt locomotive

PASSENGER INCENTIVE: $0.10/passenger

BUS

Base Wage:	$8.62/hr
Fuel, Maint., Servicing:	$0.92/bus mile
Maint. of signs, shelters:	$250/route mile
Insurance claims & Damages:	$.0065/bus mile

TABL 2-1

PAY SCALES AND UNIT COSTS OF PRESENT SYSTEM

which serve both to power the cars and to provide heat and light to the interiors. Fuel costs for the RDC's were $879,000 and were estimated by determining total yearly vehicle miles from timetable #21 and multiplying by a per-mile fuel cost of $0.31 (per-mile fuel cost was supplied by the MBTA Commuter Rail Department). During early 1978, locomotives were frequently used for power due to the unreliability of the RDC's. This change in operation is not reflected in the Base Case.

Superintendence costs and associated costs were estimated in the manner described in the introduction. However, superintendence costs were allocated to the individual lines by using an index based on the distribution of operating personnel.

2.1.2 Mechanical Department Costs

The Mechanical Department is basically responsible for the maintenance of equipments on the system. Budd cars are maintained in two locations, depending on the type of maintenance to be done. Light maintenance, which includes running repairs and inspections, is performed at the Boston Engine Terminal, while heavy maintenance, which includes major overhauls, is performed at the Billerica Back Shop. Fifty-seven percent of 1977 costs was for labor and 35 percent was for material. The costs for repairing and maintaining the Budd cars (RDC's) vary with service provided. However, the B&M back-up data does not allocate the costs by line; therefore, indices to distribute these costs by line were developed. These indices are based on the distribution of total car-miles and car assignments.

2.1.3 Engineering Department Costs

Engineering costs are basically the line- or route-specific costs of fixed structures--track, signals and bridges, and buildings. The B&M charges costs in each of the three areas directly to the individual lines; therefore, no further allocations had to be made. Thirty-one percent of total engineering costs was for track work, 31 percent for signal work and 33 percent for bridgework.

2.1.4 Other Variable Costs

In addition to the departmental variable costs, there are other costs that vary with service but do not fall into any one department. They include a passenger incentive ($0.10 per passenger) and some insurance costs (information was supplied by the MBTA); the latter was allocated to each line according to the number of cars assigned.

2.1.5 Allocated Overhead Costs

The allocated overhead costs are primarily those costs which are not directly related to the provision of service, but rather to the management functions of the B&M. They include costs for the vice presidents and staffs of the various departments (i.e., Transportation and Engineering) and costs for all other departments not directly associated with the provision of commuter rail service. Each of these cost items are allocated to the various lines by ratios based on the distribution of costs, either departmental or total.

It should be noted that if the MBTA did not contract for service, many of these costs would be fixed costs for the B&M. In actuality, many are B&M fixed costs which are allocated by the ratio of commuter service to total B&M costs and therefore by necessity vary with the amount of commuter service provided. The MBTA paid an estimated $1.4 million in overhead charges in 1977.

2.1.6 Fixed Costs

Fixed costs are mainly those costs associated with fixed facilities or areas that would have to be maintained regardless of total routes operated, e.g., the Boston Engine Terminal (BET). Fixed costs include rent and utilities for North Station; Boston terminal area costs (tower men and track, building and signal maintenance); utilities, track, building and signal maintenance associated with the Billerica repair shop and the Boston Engine Terminal; and costs for the General Manager of Commuter Services, his assistant, a special accountant and clerical support. Some of the Billerica Shop and Boston Engine Terminal costs are shared with the B&M, since they are also used for freight equipment maintenance. Total fixed costs paid for Northside service are $3.149 million. Thirteen percent is for North Station rent and utilities, 58 percent for the Boston terminal area, 21 percent for Boston Engine Terminal and the Billerica repair shop, and eight percent for staff.

2.2 SOUTHSIDE COSTS

2.2.1 Transportation Department Costs (Operational Costs)

The primary variable transportation costs are train crews, fuel, and "all other labor" costs. Southside crew costs were determined in the same manner as Northside crew costs, with one difference: a large number, if not the majority, of the crewmen were shared by the

various lines. Therefore, their wages, including pay for overtime and overmiles, had to be pro-rated by the amount of time spent on each line.

Three different types of cars--locomotives, coaches and RDC's--were used on these lines. Therefore, car-mile distributions had to be determined for each type of car before fuel costs could be calculated ($0.91/locomotive-mile and $0.31/RDC-mile). Total estimated fuel costs were $442,000. The "all other labor" category includes non-operating employees, i.e., switchtenders, herders, etc. It should be noted, however, that it was difficult to get information on the various components of these costs. They were allocated according to the number of weekly trains moving through the system.

2.2.2 Mechanical Department Costs (Maintenance of Equipment)

As on the Northside, most mechanical department costs vary with the service provided. These costs were also allocated to the various Southside lines according to the distributions of total car miles and the total number of cars assigned to each line. Labor and material account for 87 percent of Mechanical Department costs.

2.2.3 Engineering Department Costs (Fixed Structure Cost)

The maintenance of track, signals and buildings on the Shore Line and the Framingham Line is done by Amtrak and Conrail, respectively. They bill the MBTA for a portion of this cost, which accounts for 33 percent of total Southside engineering costs ($864,000). Most of the remainder of the department costs were allocated to the other lines according to the distribution of the trains moving through the system.

2.2.4 Other Variable Costs

These costs (insurance and passenger incentives) were allocated in the same manner as on the Northside (see Section 2.1.4).

2.2.5 Allocated Overhead and Fixed Costs

Southside overhead costs (estimated as $1.455 million) include "all other department costs," a management fee and various departmental costs. Fixed costs ($1.7 million) include a fee for dispatching trains (24 percent), lease costs for the Providence Engine House (20 percent), and rental, utility and other costs associated with South Station (46 percent).

3.0 CALCULATION OF COSTS FOR ALTERNATIVE RAIL PLANS

As in the Base Case, operating costs are categorized as variable, allocated overhead, and fixed, with most of the variable costs generated by the Transportation, Mechanical and Engineering Departments. Transportation costs were the most complicated to estimated requiring in some cases the development of schedules and assigning crews in addition to estimating fuel costs. Mechanical Department costs were estimated by using unit costs supplied by the MBTA. Engineering Department costs were assumed to be the same as actual Base Case costs due to the lack of a normalized maintenance policy or any real estimate of how costs would change. Allocated overhead costs were estimated as a percentage (based on the Base Case) of all other operating costs exclusive of insurance and passenger incentives. These two costs, plus the costs associated with other departments aside from those mentioned above, are categorized under "all other costs." The breakdown of operating costs by department and by commuter rail line for each alternative rail plan is presented in Tables 3-1 through 3-3.

All capital costs except those for equipment were supplied by the MBTA. Capital costs for equipment were estimated from unit costs supplied by the MBTA and allocated to a route according to the percentage of total equipment by type (e.g., percentage of locomotives and percentage of coaches) needed to provide service on that route. This avoided the biasing of costs by not assigning more costly equipment to one or two particular lines.

In contrast to the Base Case computation of costs, the costs estimated for the alternative plans were computed in the same manner for both the Northside and Southside systems, because of single ownership.

3.1 TRANSPORTATION DEPARTMENT COSTS

3.1.1 Crew and Fuel Costs

It was assumed that Plan A and Plan B would have the same crew costs as the Base Case since service is more or less identical. The only component that might change is the number of trainmen needed in Plan B;

Commuter Rail Line	Transportation Department	Mechanical Department	Engineering Department	All Other Costs	Total Operating Cost
Northside					
Eastern	3,355	1,109	1,105	1,076	6,645
Reading	1,822	945	413	824	4,005
New Hampshire	2,349	454	956	781	4,540
Fitchburg	1,638	406	716	602	3,361
NORTHSIDE TOTAL	9,164	2,914	3,190	3,283	18,551
Southside					
Framingham	617	562	39	225	1,443
Needham	1,734	1,642	375	482	4,233
Franklin	1,114	562	221	305	2,202
Providence	2,171	1,245	157	626	4,199
Stoughton	710	489	72	213	1,484
SOUTHSIDE TOTAL	6,346	4,500	864	1,851	13,561
System Total	15,510	7,414	4,054	5,134	32,112

Note: All figures in 1,000s of dollars

TAB 3-

OPERATING COST BY DEPARTMENT

Commuter Rail Line	Transportation Department	Mechanical Department	Engineering Department	All Other Costs	Total Operating Cost
Northside					
Eastern	3,324	1,112	1,105	654	6,195
Reading	1,825	939	413	477	3,654
New Hampshire	2,350	800	956	510	4,616
Fitchburg	1,638	613	716	369	3,336
NORTHSIDE TOTAL	9,137	3,464	3,190	2,010	17,801
Southside					
Framingham	617	526	39	232	1,414
Needham	1,731	719	375	421	3,246
Franklin	1,105	633	221	335	2,294
Providence	2,181	1,359	157	609	4,306
Stoughton	710	440	72	247	1,469
SOUTHSIDE TOTAL	6,344	3,677	864	1,844	12,729
System Total	15,481	7,141	4,054	3,854	30,530

Note: All figures in 1,000s of dollars

TABLE 3-2

OPERATING COST BY DEPARTMENT
(PLAN "B")

Commuter Rail Line	Transportation Department	Mechanical Department	Engineering Department	All Other Costs	Total Operating Cost
Northside					
Eastern	5,532	2,365	1,083	1,242	10,222
Reading	2,124	1,108	413	568	4,213
New Hampshire	2,801	1,164	989	673	5,627
Fitchburg	2,139	747	705	438	4,029
NORTHSIDE TOTAL	12,596	5,384	3,190	2,921	24,091
Southside					
Framingham	1,769	658	39	357	2,823
Needham	2,028	913	375	503	3,819
Franklin	2,069	881	221	487	3,658
Providence	2,968	1,739	157	793	5,657
Stoughton	1,680	681	72	403	2,836
SOUTHSIDE TOTAL	10,514	4,872	864	2,543	18,793
System Total	23,110	10,256	4,054	5,464	42,884

Note: All figures in 1,000s of dollars

TABLE 3-3

OPERATING COST BY DEPARTMENT
(PLAN "C")

however, fall counts appear to show that the majority of peak trains have an even number of cars. Therefore an additional car could be added without requiring another trainman. Equipment and crew requirements are shown in Tables 3-4 and 3-5, respectively.

In order to determine crew requirements for the Plan C system, train schedules had to be developed from a set of headways and running times supplied by the MBTA. The number of engineers required for each route was determined by dividing total daily train miles by 125 (according to the MBTA, this is the average number of miles per engineer). It was assumed that an equivalent number of conductors would be needed. The number of trainmen needed was determined by developing a peak curve for the AM peak which represents the number of riders desiring to ride the train in each 15-minute period and assigning cars to each train accordingly (generally, trainmen are not needed during much of the off-peak since trains usually consist of only one car that's open to passengers). The crew cost formulas also require the number of overmiles and overhours for each crewman. Therefore it was assumed that engineer overmiles are 25 percent above the base miles and conductor overmiles are five percent above (information supplied by the MBTA).

The average number of overhours worked by each type of crewman in the Base Case on a route-by-route basis was used.

Fuel costs were estimated by determining the number of total peak and off-peak locomotive miles and multiplying by $0.90.

3.1.2 Other Transportation Department Variable Costs

3.1.2.1 Northside

The B&M allocates most superintendence costs, which include train and crew dispatchers and timekeepers, by train-crew-labor dollars; therefore superintendence costs were estimated as a percentage of train crew costs (based on the Base Case). The cost of supplies and expenses was also estimated as a percentage of train crew costs.

It was assumed that with the exception of stationary and printing costs (estimated at 1.34 cents per passenger), associated costs, which include bridgetenders, towermen and grade-crossing protectors, would remain constant since they are basically line-fixed costs that do not vary with the level of service provided. The exceptions are: (a) the costs of bridgetenders for

	BASE[1] Locomotives/ Coaches/ Budd Cars	PLAN "A"[2] Locomotives/ Coaches/ Budd Cars	PLAN "B" Locomotives/ Coaches	PLAN "C" Locomotives/ Coaches	BUS REPLACE-MENT[3] Buses
Northside					
Eastern	0/0/24	7/19/5	7/26	12/59	38
Reading	0/0/21	5/16/5	5/24	5/29	18
New Hampshire	0/0/14	4/14/0	4/21	5/31	32
Fitchburg	0/0/11	4/11/0	4/14	5/16	19
NORTHSIDE TOTAL	0/0/70	20/60/10	20/85	27/135	107
Southside					
Framingham	3/13/0	3/13/0	3/13	4/15	18
Franklin	1/07/6	3/13/0	3/17	4/22	26
Needham	4/16/2	4/05/13	4/18	5/23	16
Shore Line	10/43/2	10/45/0	10/45	12/61	61
SOUTHSIDE TOTAL	18/79/10	20/76/13	20/93	25/121	121
System Total	18/79/80	40/136/23	40/178	52/256	228

[1] Only Budd cars were used on the Northside in the Base Case.

[2] Assumes rental of "GO Coaches" from Toronto

[3] See Chapter 4.0 for a description of this alternative.

TABLE 3-4

EQUIPMENT REQUIREMENTS

	BASE Eng/Cond/Trnm*	PLAN "A" Eng/Cond/Trnm	PLAN "B" Eng/Cond/Trnm	PLAN "C" Eng/Cond/Trnm	BUS REPLACE- MENT** SYSTEM Drivers
Northside					
Eastern	15/15/11	15/15/11	15/15/11	31/31/27	39
Reading	08/08/09	08/08/09	08/08/09	13/13/13	18
New Hampshire	11/10/09	11/10/09	11/10/09	16/16/14	35
Fitchburg	08/08/06	08/08/06	08/08/06	13/13/08	22
NORTHSIDE TOTAL	42/41/35	42/41/35	42/41/35	73/73/61	114
Southside					
Framingham	03/03/05	03/03/05	03/03/05	10/10/08	18
Franklin	03/03/05	03/03/05	03/03/05	10/10/11	28
Needham	06/07/08	06/07/08	06/07/08	09/09/10	16
Shore Line	10/08/17	10/08/17	10/08/17	24/24/25	67
SOUTHSIDE TOTAL	22/21/35	22/21/35	22/21/35	53/53/54	129
System Total	64/62/70	64/62/70	64/62/70	126/126/115	243

*Engineers/Conductors/Trainmen

**See Chapter 4.0 for a description of this alternative.

TABLE 3-5

CREW REQUIREMENTS

Draw 7 on the Eastern Route were excluded for all alternatives and (b) the costs for all towermen were excluded in the Plan C system alternative.

3.1.2.2 Southside

Although it was assumed that "all other labor" costs ($1.55 million) vary with the level of service provided, no attempt was made to adjust them accordingly because of the problems with determining the individual components.

3.2 MECHANICAL DEPARTMENT COSTS

The following unit maintenance costs (supplied by the MBTA) were used to determine Mechanical Department costs: old locomotives, $87,000; rebuilt locomotives, $56,000; new locomotives, $49,500; old coaches, $18,000; new coaches, $24,500; G.O. coaches, $15,000; old Budd cars, $79,000. Maintenance of equipment costs were allocated to a route according to the percentage of total equipment by type (i.e., percentage of locomotives and percentage of coaches) needed to provide service on that route. This procedure avoided the biasing of costs by not assigning more costly equipment to one or two particular lines. (It should be noted that specific types of equipment were assigned to routes in Plan A because of technical requirements.)

3.3 ENGINEERING DEPARTMENT COSTS

Due to a great deal of inconsistent data and the lack of a normalized maintenance policy, it was assumed that the level of spending in the department would remain the same. It should be noted that actual costs were available for this department by the end of the study and were used in the alternatives because they were deemed to be more justifiable.

3.4 ALLOCATED OVERHEAD AND OTHER COSTS

"All Other Department" costs and the management fee on the Southside were estimated as a percentage (based on Base Case) of operating costs exclusive of passenger incentives and insurance. The passenger incentive is estimated at ten cents per passenger and insurance costs were estimated at $4,400 per vehicle.

Leasing costs of $24,000 per coach were also included in the Limited Investment Alternative.

3.5 CAPITAL COSTS

Capital costs (excluding equipment costs) for each alternative were supplied by the MBTA. The following unit costs were used to determine equipment costs: new locomotive, $876,000; rebuilt RDC, $300,000; new coach, $450,000. Equipment costs were then allocated to each line according to the percentage of total coaches assigned. The type of coach (i.e., converted RDC vs. new coach) assigned to individual lines was disregarded since it was assumed that they would be completely interchangeable; therefore all lines should share the costs.

Annualized capital costs were determined on a project-by-project basis according to an assumed lifespan for each project using six and nine percent discount rates. Capital costs for these alternative rail plans are shown in Tables 3-6 through 3-8.

NORTH SIDE

	Gloucester Branch	Eastern Route Boston to Ipswich	Reading	New Hampshire Including Woburn Branch	Fitchburg Division	North Side Central Systems & Facilities	North Side Total
EQUIPMENT							
Locomotives	350	2,103	1,753	1,402	1,402		7,010
Coaches	4	42	40	26	21		133
REPAIR-MAINTENANCE FACILITIES							
LAYOVER FACILITIES							
TRACK	5,130	4,636	114	1,930	3,587		15,397
BRIDGES	162	13,720				145	14,027
SIGNALS	130	380	77	630	815	312	2,344
STATIONS							
PARKING							
ADDITIONAL TRACK OR R-O-W							
TOTAL	5,776	20,881	1,984	3,988	5,825	457	38,911

SOUTH SIDE

	B & A Framingham	Needham	Franklin	Shore Providence	Stoughton	South Side Central Systems	South Side Total
EQUIPMENT							
Locomotives	1,052	1,402	1,052	2,804	700		7,010
Coaches	24	34	24	62	23		167
REPAIR-MAINTENANCE FACILITIES						5,500	5,500
LAYOVER FACILITIES							
TRACK		1,180	1,463		100		2,743
BRIDGES							
SIGNALS		no. est.	no. est.		no est.		
STATIONS							
PARKING							
ADDITIONAL TRACK OR R-O-W							
TOTAL	1,076	2,616	2,539	2,866	823	5,500	15,420
						TOTAL PLAN "A"	54,331

CAPITAL COSTS FOR PLAN "A" (LIMITED INVESTMENT)
(IN $1,000s)

TABLE 3-6

NORTH SIDE

	Gloucester Branch	Eastern Route Boston to Ipswich	Reading	New Hampshire Including Woburn Branch	Fitchburg Division	North Side Central Systems & Facilities	North Side Total
EQUIPMENT							
Locomotives	350	2,103	1,753	1,402	1,402		7,010
Coaches	529	6,306	6,306	5,520	3,681		22,342
REPAIR-MAINTENANCE FACILITIES						6,500	6,500
LAYOVER FACILITIES							
TRACK	7,360	9,110	1,375	9,020	11,880		38,745
BRIDGES	2,500	17,250	1,000	500	500		21,750
SIGNALS	455	847	181	1,280	1,255	737	4,755
STATIONS							
PARKING							
ADDITIONAL TRACK OR R-O-W							
TOTAL	11,195	35,616	10,614	17,722	18,718	7,237	101,102

SOUTH SIDE

	B & A Framingham	Needham	Franklin	Shore Providence	Stoughton	South Side Central Systems	South Side Total
EQUIPMENT							
Locomotives	1,052	1,402	1,052	2,804	700		7,010
Coaches	3,415	4,730	4,468	8,674	3,153		24,440
REPAIR-MAINTENANCE FACILITIES						5,500	5,500
LAYOVER FACILITIES							
TRACK		1,620	2,830		390		4,840
BRIDGES		600					600
SIGNALS		1,850			20		1,870
STATIONS							
PARKING							
ADDITIONAL TRACK OR R-O-W		3,230					3,230
TOTAL	4,467	13,432	8,350	11,478	4,263	5,500	47,490
						TOTAL PLAN "B"	148,592

CAPITAL COSTS FOR PLAN "B" (STABILIZED SERVICE)
(IN $1,000s)

TABLE 3-7

NORTH SIDE

	Gloucester Branch	Eastern Route Boston to Ipswich	Reading	New Hampshire Including Woburn Branch	Fitchburg Division	North Side Central Systems & Facilities	North Side Total
EQUIPMENT							
Locomotives	944	4,719	2,360	2,360	2,360		12,743
Coaches	2,889	16,106	9,626	10,171	5,329		44,121
REPAIR-MAINTENANCE FACILITIES						19,000	19,000
LAYOVER FACILITIES	Decisions needed on Locations						-
TRACK	9,260	15,700	5,555	18,540	23,240		73,295
BRIDGES	5,065	32,250	1,000	500	500		39,323
SIGNALS	4,105	9,325	2,300	9,080	14,780	7,362	46,952
STATIONS	Information not available yet						-
PARKING	Information not available yet						-
ADDITIONAL TRACK OR R-O-W	-	-					
TOTAL	22,263	79,110	20,841	40,551	46,209	26,362	235,435

SOUTH SIDE

	B & A Framingham	Needham	Franklin	Shore Providence	Stoughton	South Side Central Systems	South Side Total
EQUIPMENT							
Locomotives	1,887	2,360	1,887	4,244	1,413		11,791
Coaches	4,994	7,293	7,578	14,207	5,899		39,971
REPAIR-MAINTENANCE FACILITIES						18,000	18,000
LAYOVER FACILITIES	Decisions needed on Locations						-
TRACK		3,890	6,950		1,520		12,360
BRIDGES		600			300		900
SIGNALS		1,850	3,775	-	430		6,055
STATIONS	Information not available yet						-
PARKING	Information not available yet						-
ADDITIONAL TRACK OR R-O-W		3,230	2,620				5,850
TOTAL	6,881	19,223	22,810	18,451	9,562	18,000	94,927
						TOTAL PLAN "C"	330,353

CAPITAL COSTS FOR PLAN "C" (FULLY RESTORED SYSTEM)
(IN $1,000s)

TABLE 3-8

4.0 CALCULATION OF COSTS FOR BUS REPLACEMENT ALTERNATIVE

4.1 GENERAL STRATEGY

EOTC's first step in designing replacement service for each rail line was to examine travel patterns on the line. Results of ticket audits and of the 1976 on-board survey showed that with the exception of the Eastern and Fitchburg routes, the volume of travel between station pairs outside Boston is negligible. Therefore a decision was made to ignore on-line trips except for the two routes cited above. On the Eastern Route about 12 percent of all trips are made between stations outside Boston. However, a more detailed examination revealed that the local trip pattern is unstable and is therefore almost impossible to design replacement service for. This resulted in a decision to design a network for the needs of the Boston trips only, as in the majority of corridors.

On the Fitchburg Route about 25 percent of all trips are made between stations outside of Boston. More than half of this local travel is accounted for by trips to or from Cambridge Station at Porter Square. This volume was sufficiently great to justify establishment of bus service from suburban stations to Cambridge as well as to Boston. Cambridge routes were designed to serve Harvard Square directly.

The location of the downtown terminal is an important factor in determining the market for commuter rail service. All Northside rail lines terminate at North Station, but the majority of users of the service have destinations nearer to downtown Boston. Bus routes to replace Northside commuter rail were designed to terminate at Haymarket Square rather than North Station because this would be more convenient for most riders. However, the existing Haymarket bus terminal is already quite congested during peak hours. Additional facilities would be needed in order to accommodate the number of buses required for rail replacement service. Another possibility would be conversion of North Station to a bus terminal, but this is a less favorable location than Haymarket for bus access as well as for pedestrian access.

All Southside commuter rail routes terminate at South Station, and include a stop at Back Bay. During

construction of the relocated Orange Line, trains on the Providence, Stoughton and Franklin routes will bypass Back Bay, but some form of substitute service to Back Bay will be provided. When construction is completed, trains will again serve Back Bay. Bus routes to replace Southside commuter rail service were designed to serve South Station and Copley Square. Because of traffic congestion between these points, separate routes to the two stations would be provided if volume is sufficient.

Schedules for buses replacing rail service were developed on the basis of existing rail schedules and volumes. In general it was assumed that buses replacing inbound trains should maintain the current Boston departure times. Some adjustments from this were made in order to improve utilization of operators and vehicles. In cases where volume required more than one bus at a station to replace a certain train it was assumed that departures would be staggered in order to provide more choice for users.

Initially it was felt that replacement buses should be designed to serve the same communities served by commuter rail, but did not necessarily have to run directly to all railroad stations. Most replacement routes were ultimately designed to serve existing station sites in order to take advantage of parking lots. Sites of additional stops are not identified specifically in most cases, but assumed running speeds through densely populated areas would allow some extra stops. Such extra stops would reduce access distance for certain users, and would partially compensate for the longer line-haul time of buses compared to rail service. Analysis of origins of rail users found several cases in which there is a large volume of park-riders that would be better served by a station located at a new site. Bus routes to serve these new facilities were included in the replacement network. For example, nearly one-third of the users of Beverly Station live outside Beverly and could reach North Shore Shopping Center as easily as Beverly Station. There is already small-scale private-carrier bus service between the shopping center and Boston. Bus time from that point to Boston is less than bus time from Beverly to Boston, and diversion of park-riders to the shopping center would reduce congestion in downtown Beverly. For the benefit of riders living in Beverly there would also be bus service to Beverly Station, however. For the number of buses assigned on each line, see Table 3-4 in Section 3.1.1.

4.2 CREW ASSIGNMENTS

The first step in estimating the cost of bus replacement services was to assign drivers to the various routes. In assigning drivers, it had to be remembered that they can work a maximum of eight hours per day; however, these eight hours can be spread over a thirteen-hour period. Work performed between the 10th and 11th hour on duty is paid at time and a half and any work performed after the 11th hour is paid at double time. Due to the nature of service (peak hour only) on the majority of the routes, drivers would actually spend only four or five hours of the eight-hour work day in revenue service. However, two or three of these hours would be paid at overtime rates since they occur after the 10th hour of the shift. (This situation could be improved significantly by employing part-time drivers; however, union rules do not allow this practice.)

It was found that the most efficient utilization of drivers occurs on the Eastern Route, where 63 percent of the drivers' time is spent in revenue service and only 14 percent of the eight-hour shifts is overtime. It should be pointed out that this group of routes has a significant amount of off-peak service. The Franklin Replacement Service is the least efficient. Only 55 percent of the drivers' time is spent in revenue service, and 18 percent of the eight-hour shifts is overtime. See Table 3-5 for the distribution of drivers on each commuter rail line.

4.3 GROSS OPERATING COSTS

The costs of operating the various replacement services were divided into the following four categories: (a) bus-mile variable costs, which include fuel, servicing, repairs, miscellaneous bus service employees and various other transportation expenses; (b) bus-hour costs, which include the wages and fringe benefits of bus drivers and their supervisors; (c) variable route-mile costs, which include costs of shelters and bus stop signs; and (d) costs of injuries, damages and claims. Cost formulas which EOTC staff developed in 1975 had to be updated to allow for present operating costs. 1977 costs were not available for the elements included in the first category; therefore, the percent change in the cost of each element between 1975 and 1976 was applied to 1976 costs to estimate the 1977 variable cost per bus-mile. The bus-hour cost formula was updated by using the 1977 wage rate. (It should be noted that a separate formula had to be developed for each service because the factor, which includes fringe

benefits, overtime pay, deadheading, the amount of time spent in non-revenue service and superintendence, was different for each service.) The variable route-mile cost formula was not updated because of the difficulty in estimating costs from available data due to the overlapping of many routes. The formula for the costs of injuries, damages and claims was not adjusted because it is already based on five-year average costs. The 1977 formulas for estimating costs of bus replacement service are as follows:

A) Bus-mile variable cost: (Bus-miles)($0.92)

B) Hourly cost:
(scheduled run-time & delay time + layover time) x (($8.62)(total bus trips))(factor*)

C) Route-mile cost: $250/route-mile/year

D) Injuries, damages and claims settled:
$6,500/100,000 bus-miles

Operating costs by department and by rail line for this alternative are shown in Table 4-1.

Weekend schedules were not developed for these services; however, an EOTC study revealed that yearly costs (including weekend service) can be approximated by multiplying daily costs by a factor of 300.

There are fixed costs associated with the provision of bus service; however, it is almost impossible to allocate them to separate groups of routes because of the large number of bus routes that the MBTA operates. An attempt was made to estimate the 1977 costs of the various elements that make up overhead costs, in the same manner in which the elements of bus-mile variable costs were estimated, since it is known that they inflate at different rates. However, it was found that many of the elements vary greatly from year to year. Therefore, 1975 overhead costs as a percentage of 1975 variable costs and 1976 overhead costs as a percentage of 1976 variable costs were averaged, and the resulting percentage was applied to the variable costs of each route to determine overhead costs.

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*The factors are: Eastern Rte., 2.81; New Hampshire Rte., 3.12; Fitchburg Rte., 2.94; Providence & Stoughton Rte., 3.15; Franklin Rte., 3.30; Reading Rte., 2.40; Needham Rte., 2.40; Framingham Rte., 3.59.

Commuter Rail Line	Transportation Department	Mechanical Department	Engineering Department	All Other Costs	Total Operating Cost
Northside					
Eastern	1,358	1,167	82	425	3,032
Reading	581	201	-	113	895
New Hampshire	1,302	1,095	44	399	2,840
Fitchburg	834	487	-	218	1,539
NORTHSIDE TOTAL	4,075	2,950	126	1,155	8,306
Southside					
Framingham	392	306	-	107	805
Needham	455	293	-	113	861
Franklin	1,050	837	162	336	2,385
Providence / Stoughton	2,527	2,259	181	812	5,779
SOUTHSIDE TOTAL	4,424	3,695	343	1,368	9,830
System Total	8,499	6,645	469	2,523	18,136

Note: All figures are in 1,000s of dollars

TABLE 4-1

OPERATING COST BY DEPARTMENT
(BUS REPLACEMENT SERVICE)

4.4 CAPITAL COSTS

Capital costs, which include equipment, two bus terminals and a garage, were estimated by EOTC. Annualized capital costs were determined according to the assumed life span of each project by using six percent and nine percent discount rates. In order to operate the bus replacement alternative, the MBTA would need to purchase 262 new buses, build two new bus garages, and provide three new or rebuilt terminal facilities, at a total capital cost of $31,460,000. This is an annualized cost of $3,904,000 (capital costs include cost for garage and terminal facilities).

TECHNICAL APPENDIX A.2

TITLE ANALYSIS AND FORECASTING OF RIDERSHIP FOR COMMUTER RAIL SERVICE ALTERNATIVES

AUTHOR(S) API RUZDIC, EVELYN ADDANTE

DATE MAY 1979

ABSTRACT This appendix documents the travel-demand analysis conducted for the CRIP study. It includes a description of travel demand theory, the models developed for the study, and data requirements.

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CENTRAL TRANSPORTATION PLANNING STAFF 27 School Street, Boston, Mass. A Cooperative Planning Effort of MAPC, EOTC, MDPW, MBTA, MBTA ADV. BD., MASSPORT.

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1.0 SUMMARY

1.1 METHODOLOGY

The travel-demand analysis conducted for the CRIP study used disaggregate models. It considered the decisions travelers make in relation to trip destination and travel mode, and it was founded on the assumption that these decisions are affected by the travel time and cost of the travel alternatives available to the individual as well as his personal tastes and socio-economic characteristics.

To determine how a given change in the transportation system is likely to affect these two kinds of decisions, it is necessary to trace the effects of changes in travel time and cost through the entire travel-decision process. The models developed for this study are based on choice theory and use individual consumers, e.g., a household or an individual as a unit of observation.

In choice theory, it is assumed that an individual will select the option from which he derives the greatest utility based on his individual utility function. A utility function measures the value placed on each travel option by an individual according to the service characteristics of that option and his own socio-economic characteristics. Since there is always some uncertainty in the measurement of this function, it is only possible to determine the probability that a particular alternative will be selected. Assuming probabilistic behavior rather than the deterministic behavior of traditional theories makes it possible to explain the existence of different choices for the same set of observed variables.

The CRIP study examined the two most frequent trip purposes - work trips and shopping trips and this dictated development of two classes of models: a mode choice model for work trips and a destination and mode choice model for shopping trips. Mathematically a logistic curve served as a basis for modeling the choice of individuals. A logistic function suggests that the probability of an individual choosing a particular mode out of a set of available alternatives is based on the observations of past behavior in similar circumstances. The formulation is a function of an individual's utility for alternative travel options.

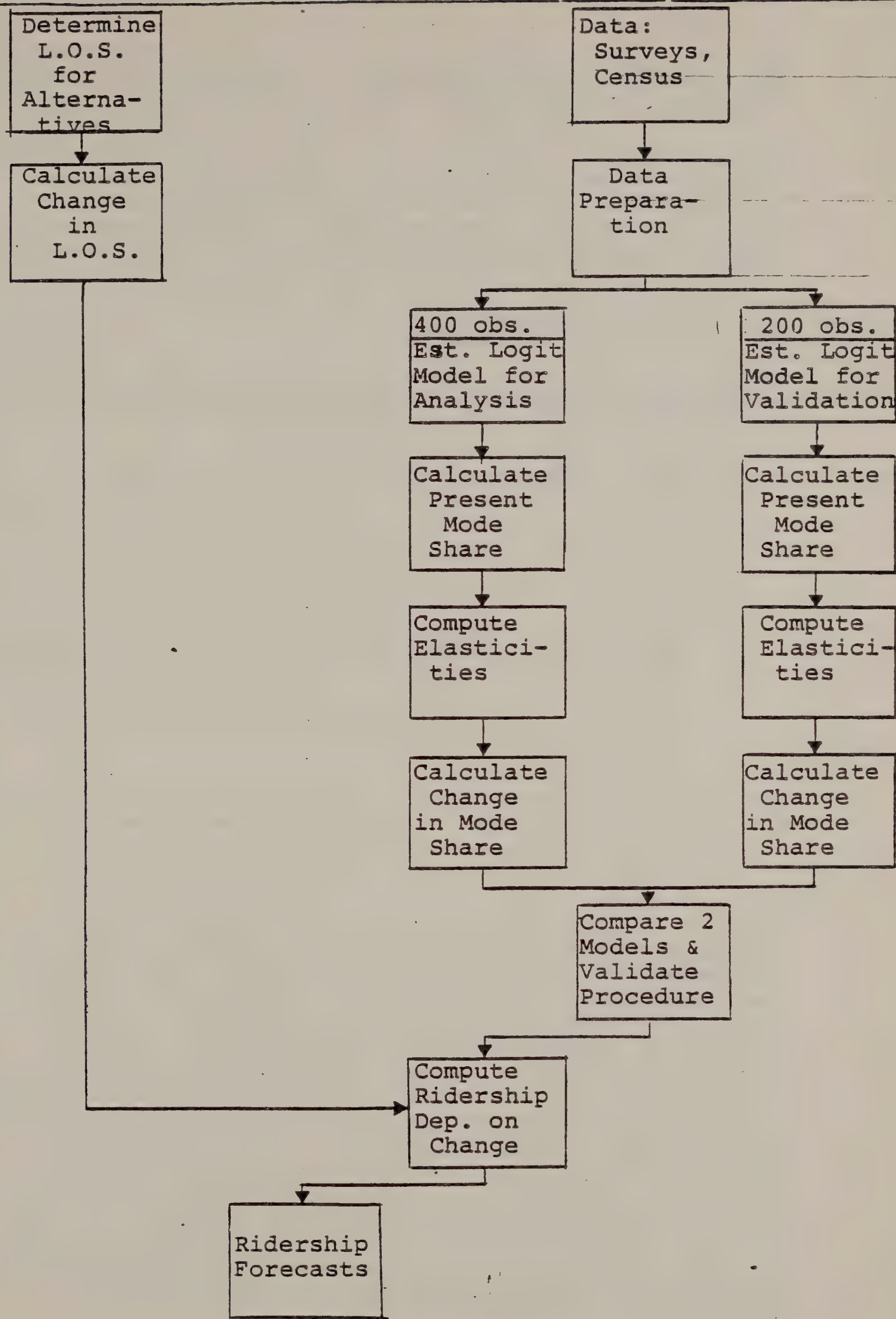
The utility of a particular mode is dependent on certain level of service characteristics of that mode and on certain socio-economic characteristics of the individual. Specifically, the variables included in the utility functions for the work trip model were in-vehicle and out-of-vehicle travel time, out-of-pocket costs, annual household income, number of persons per household, the number of cars divided by the number of licensed drivers, the position in the household and occupation of the individualtraveler. For the shopping trip model a retail employment variable was added to the same variables used in the work trip choice model. In the model chosen for this analysis, specifications of all of the variables except those of household size and the occupation of the traveller were represented.

To calibrate the relationship between the probabilities of chosing a specific alternative and an individual's utility function, observations of actual travel choices were used together with the socio-economic characteristics of the decision-maker and the level of service characteristics of available transit modes.

The data used to estimate these models came from a number of different sources (e.g., the 1976 Commuter Rail Survey, the 1977 North Shore bus survey, 1970 Census, and 1963 Home Interview Survey). A sample of 600 observations was developed from these sources; 400 to be used for model calibration and 200 for model validation.

Since disaggregate models require transportation system level-of-service data and socio-economic for each decision-maker, it was necessary to transform much of the available data from a zonal base to the required format. The data used to estimate the logit models was composed of a sample of actual mode choices given certain level-of-service variables and socio-economic characteristics. Once the individual probabilities were determined from the estimation of the models, the results were summed up to determine the mode split. These results were then validated using the additional sample of 200 observations.

The next step in the travel forecasting process was to mathematically derive elasticities from the the estimated coefficients of the logit models. Elasticities measure the percent change in mode share from a one percent change in level of service variables. To determine how the specified capital investments in commuter rail would affect service levels a number of



TRAVEL FORECASTING METHODOLOGY

FIGURE 1-1

key variables were selected including 1) frequency of service, 2) running times and 3) reliability of service for each of three modes: auto, rail and bus.

The change in these level of service variables for each alternative was computed and compared to existing commuter rail level of service characteristics. The elasticities were then applied to current rail ridership to obtain ridership forecasts for each alternative.

1.2 POLICY IMPLICATIONS

The policy implications which can be drawn from the estimated models, given the limitations of the data from which they are estimated, are:

- Those people having access to a car are very likely to use the car for work trips.
- Those people having access to a bus and train only are very likely to use the train.
- The chance that a given person will choose to use a car increases as the trip length increases.
- Out-of-pocket travel costs have a very small effect on mode choices (with data utilized in this study).
- Out-of-vehicle travel time is considerably more burdensome than in-vehicle travel time, with the time taken to park a car being particularly onerous.

A major concern of the study was to predict total travel demand per facility under different transit improvement programs. The methodology applied is best explained with a simple illustration. Much can be learned about travel and the influence on that demand of various engineering and policy measures, through analysis of demand elasticities (the proportional change in demand due to specified changes in the independent variables included in the model). The effects of mode choice from specific policy or engineering measures have been calculated. For example, simultaneous introduction of an increase in the out-of-vehicle travel time for car trips by 30 percent together with a 20-percent reduction in out-of-vehicle travel time (walking and waiting) by train results in a two-fold increase in the number of public transit users.

The findings of the study are in agreement with the results of the research in the field as well as a priori expectations based on the experience with the system.

1.3 OUTLINE OF THE APPENDIX

Chapter 2 provides a discussion of forecasting models, reviews the structure of the prediction process in transportation planning and describes forecasting procedures.

Chapter 3 describes the travel theory used in the study, the variables of the model and the estimation technique..

Chapter 4 reviews the data used in the models and the processing of that data.

Chapter 5 introduces the work mode choice model, the variables and specification of the model.

Chapter 6 describes the shopping-trip mode and destination choice model and compares it with the work mode choice model.

2.0 FORECASTING MODELS

2.1 INTRODUCTION

In transportation planning, forecasting models are used to predict the consequences of alternative plans and policies. Almost invariably there is a wide range of alternatives that need to be evaluated. These alternatives consist of specific configurations of the supply of transportation services, where supply is defined as both qualitative and quantitative changes in the level of service provided by a transportation system.

Possible transportation-system-supply configurations are many and varied, some of which result from explicit policies and others which are to a greater or lesser extent uncontrollable. Some of these changes are as follows:

- Changes in transit service and operations
- Alterations in transportation pricing
- Reduced energy availability.

Each of these transportation supply shifts has a great number of potential impacts which must be considered in evaluating alternative policies. Air quality, energy consumption, noise levels, the economic viability of transit systems and levels of congestion all depend to some extent on the nature of the transportation system. The core of forecasting these impacts is the prediction of travel demands, i.e., the amount and nature of travel likely to utilize the transportation system.

There are four basic alternative approaches to travel-demand models:

1) Aggregate simultaneous models - Charles River Associates' San Francisco demand model (CRA, 1967),

2) Aggregate recursive models - the traditional UTPS models,

3) Disaggregate simultaneous models - as estimated by Ben-Akiva (1973),

4) Disaggregate recursive models - the disaggregate modal split models (Reichman and Stopher, 1971: PMM, 1972) and the more recent demand model estimated by CRA (1973).

In addition to these four alternative model-estimation approaches, there are also two ways to use the estimated models in predictions. The two alternative ways of predicting trips for a specific purpose characterized by its origin (i), destination (d) and mode (m) are:

1) Direct - directly predicting the volume of trips V_{idm}, for example (this is the predictive counterpart of simultaneous model estimation)

2) Indirect - predicting V_i first, then V_{id}, and finally V_{idm}, for example (this is the forecasting counterpart of recursive model estimation).

The current trend in travel forecasting and the approach pursued in this study is toward disaggregate simultaneous models and direct forecasting.

2.2 INTERACTION BETWEEN LOCATION AND TRANSPORT

Travel is almost always undertaken for a certain purpose that can be served at a destination of a trip. The exception is a pleasure ride which is made solely for its own sake, but such trips are relatively infrequent and probably non-existent in dense urban traffic. Hence, if the traveler does not derive any utility from the trip by itself, travel can most logically be considered an intermediate good (Oi and Shuldiner, 1962; Kraft and Wohl, 1967). The demand for such an intermediate good is derived from the consumption of the final good.

In the case of travel, the final good is the activity at the destination of the trip; e.g., work, shopping, etc. The demand for this activity is in turn a function of its price, which includes the cost of the associated trip as well as non-monetary costs such as time, convenience, comfort, etc. Given the demand for this activity, the demand for trips alone can at least be conceptually derived. As an example, consider the demand for theater visits. It will depend, among other things, on the price of the ticket and the cost of the trip to the theater, including parking fee if a car is used. The demand for trips to the theater is hence determined from the demand for theater visits.

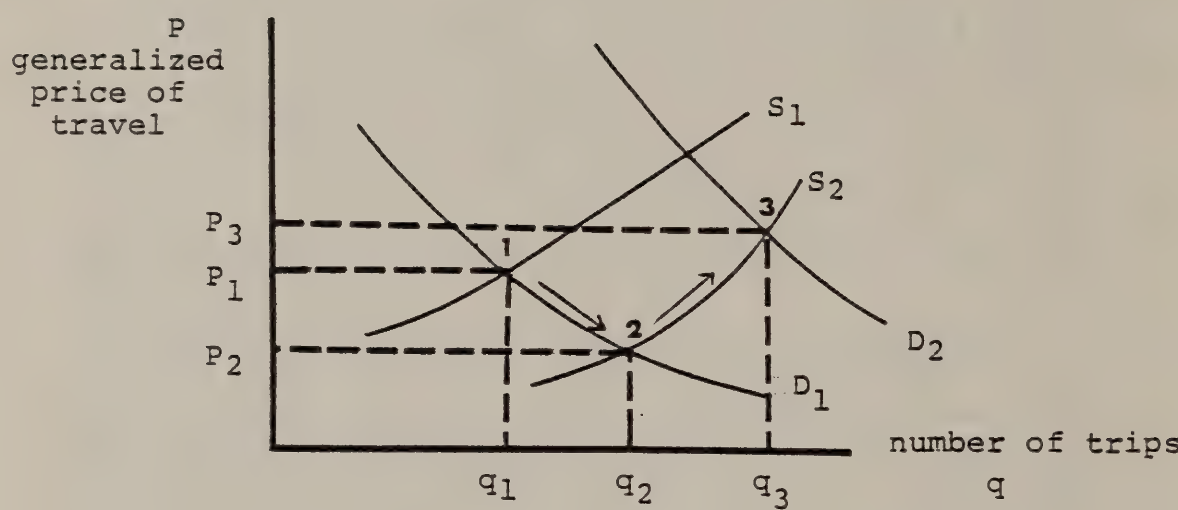
2.2.1 Transportation Demand and Population Shifts

The local decisions of decision-makers in firms, households, and in the public sector ultimately determine the pattern of trips for the various activities, and the available supply of transportation influences these location decisions. This observation brings out a rather unique case of a limited demand curve.

In general, a demand curve in a classical economic static framework is assumed to shift due to income changes and changes in prices of other commodities, and aggregate demand will shift also due to natural growth of the population. However, in the case of transportation, in addition to the usual demand shifts, the improved accessibility may attract new locators which will further increase the volume of trips, or actually shift the demand curve to the right. Furthermore, there may be shifts to the left in locations where the supply does not change, since locations are often in competition as locational alternatives for households and firms.

This behavior is illustrated in Figure 2-1. The demand curve D_1 is the curve that is in effect with the supply curve S_1. The equilibrium volume of trips is q_1 at a generalized travel price (including both money outlay and travel time) of p_1. An improvement in the transportation system results in a new supply curve, S_2. The new equilibrium volume and price are q_2 and p_2, respectively. However, this is only a short-run equilibrium. In the longer run the demand curve can be expected to shift to the right along the supply curve S_2 and the demand curve D_2. The shift of the demand curve from D_1 to D_2 is conventionally attributed to changing income, prices of other commodities and exogenous population changes. However, in our case, part of the shift is attributed to the fact that the supply curve shifted from S_1 to S_2. The long-run equilibrium is q_3 and p_3.

It may be argued that the supply of transportation plays only a minor role in determining the total magnitude of many activities, and that therefore the demand shift attributed to the change in supply is negligible. However, while the total magnitude of activities (e.g., the number of households) is relatively unaffected by supply changes, the spatial distribution of the activities is directly related to transportation (Meyer, 1963). Since demand for travel makes no sense unless it is spatially disaggregated, the shift in the demand curve will be caused primarily by the changing distribution of activities.



TRAVEL DEMAND SHIFTS DUE TO SUPPLY CHANGES

FIGURE 2-1

The implication of this interaction between location and transportation is that if we want to properly evaluate major changes in transportation services, we should model the effect of transport on the spatial distribution of activities. In particular, we should model the locations decisions of potential travelers, which are closely related to their travel demand.

For example, an improved transit service on a given line will attract more riders but will also influence people who consider using the service to locate near the line stations. More dramatic effects have been observed in the implementation of urban freeways. Initial designs based on travel demand forecasts that failed to adequately account for significant population shifts resulted in facilities such as the Long Island Expressway in New York being congested almost from the time they were opened.

It is principally because travel demand shifts as a result of changes in the transportation supply that transportation planners have found it essential to forecast population. This, accompanied with the need for predictions which are spatially disaggregated, requires that small-area population forecasts must be made as an integral part of the transportation planning process.

2.3 STRUCTURE OF PREDICTION PROCESS IN TRANSPORTATION PLANNING

The foregoing discussion described the interactions of the travel-demand function with the location of activities and the supply of transport services. We proceed now to outline a structure for prediction in transportation planning for which the forecasting of small-area population is a part.

The problem of prediction in transportation planning is to anticipate the impacts from a proposed change in the transportation system. We can distinguish between two types of impact: internal and external. The internal impacts depend on the new equilibrium in the transportation system. The external impacts depend on the effects the change in the transportation system has on the equilibrium of related markets. We will refer to these markets, which constitute the environment of transportation, as the activity system. For example, construction of a new highway will affect the equilibrium in the transportation network. In addition, it will also affect the activity system; e.g., changes in population distribution in the vicinity of the highway, changes in the production costs of manufacturing firms located near the highway, etc.

In general, the transport planner cannot directly change the activity system. However, it is evident that changes in the activity system will have a very significant effect on transportation and that meaningful forecasts of demand must explicitly consider such changes.

Conceptually, the basic problem for the transport planner is to predict the equilibrium in the transportation system. This equilibrium, or pattern of flows in the transportation network, consists of the volumes of trips and the service levels experienced by those volumes.* In the short run the flow pattern is the result of an equilibrium between supply and demand. This pattern of flows has as its consequences a broad range of impacts such as energy usage, costs, pollution, land use, etc. These impacts will be called resource consumption, and can be forecast as a consequence of travel flows.

This short run equilibrium is depicted in Figure 2-2. Supply-and-demand functions are solved simultaneously, and resource consumption is forecast as a result of the equilibrium.

However, the modelling structure required to forecast the long-run equilibrium must also account for activity system shifts. This structure is depicted in Figure 2-3. As before, supply and demand are equilibrated, but an additional factor, activity shifts, has been added. These shifts are in turn an input to the demand model. It is this feedback loop that produces some of the most difficult methodological problems in transportation planning, since the population for which travel demand is being forecasted is in itself affected by the policies under consideration.

2.4 FORECASTING PROCEDURE

Our approach is based on the intuitively simple observation that "zones don't commute--people commute" (McFadden and Reid, 1975). In order to represent the decisions which determine the impacts of transportation in a behavioral way, transportation planners have

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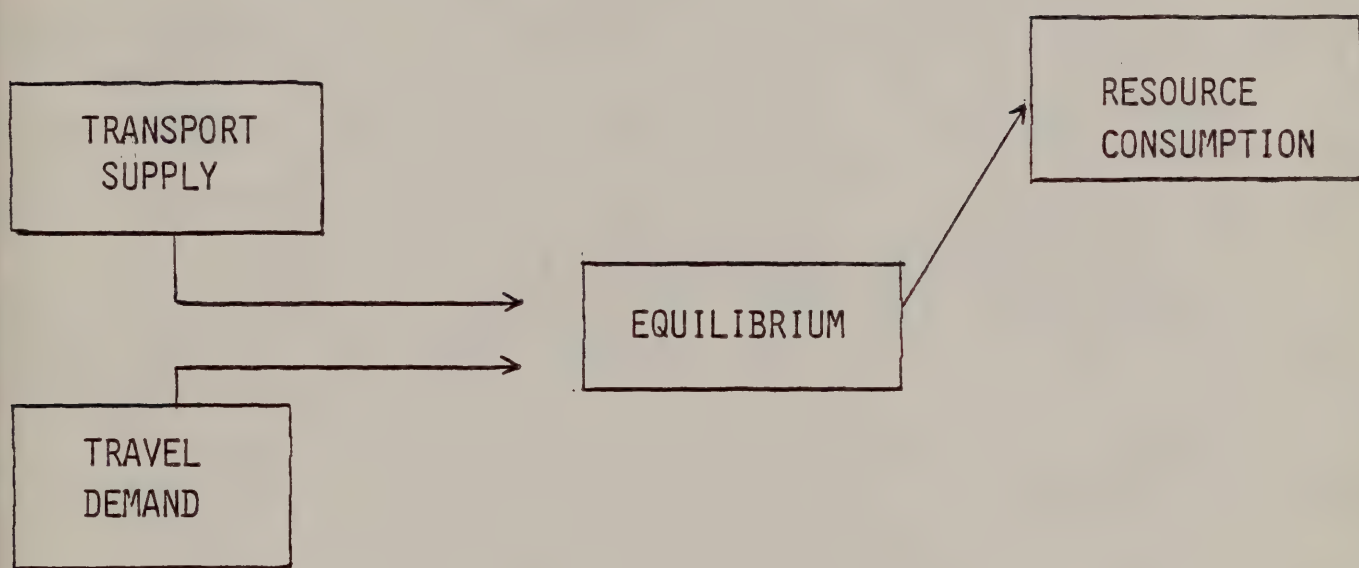
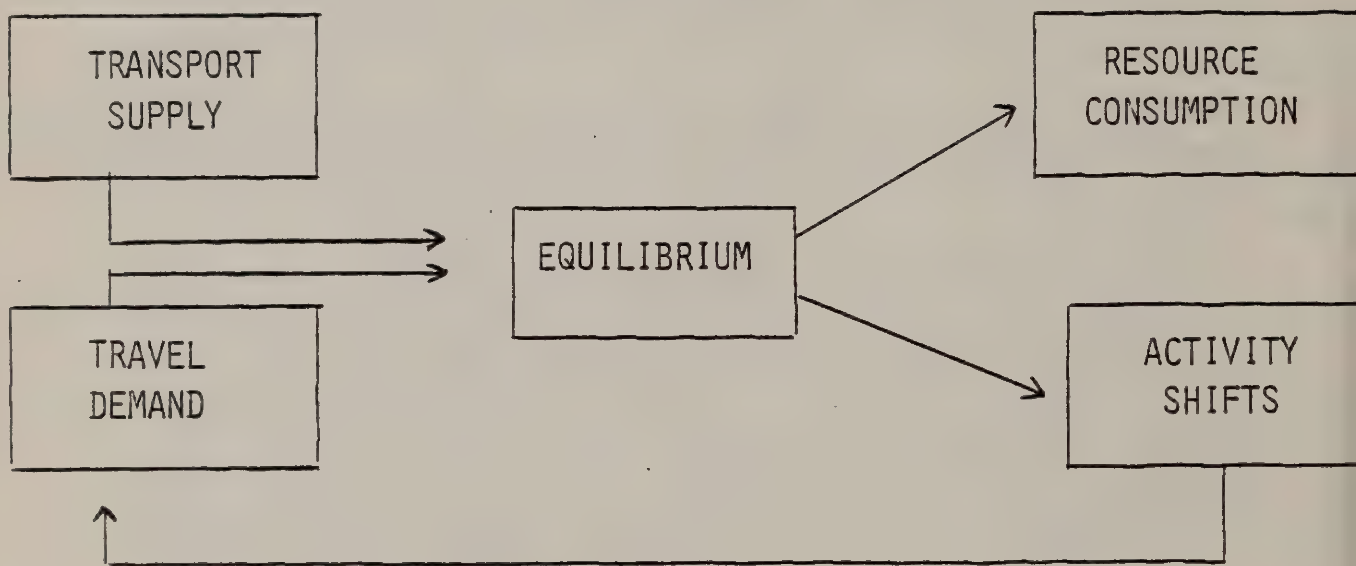
*By service level we refer to all the service characteristics of a trip: travel time, travel cost, safety, comfort, etc. We can regard this service level as a vector of prices that if combined can be regarded as a generalized price. Similarly, volume can be regarded as movements of vehicles, goods or people by more than one mode.



SHORT RUN EQUILIBRIUM

FIGURE 2-2



LONG RUN EQUILIBRIUM

FIGURE 2-3

turned to modelling approaches which utilize the choices of individual decision-makers (in general, households or individual travelers) as the unit of observation. These models have generally been termed disaggregate behavioral models.

In order to develop disaggregate models, transportation planners have adopted a choice theory perspective initially developed by mathematical psychologists (Luce and Suppes, 1965). The analytic details of this methodology are developed in numerous references (e.g., Ben-Akiva, 1973; Charles River Associates, 1972) and will not be explored here. It suffices to state that choice theory is concerned with the behavior of an individual decision-maker confronted with a set of alternatives from which one and only one must be selected. The decision-maker is assumed to assess each option with a utility function and select the option from which he derives the greatest utility. However, because there is always some uncertainty in the measurement of this utility function, it is impossible for an observer to know which alternative the decision-maker will select; only the probability of selection for each alternative can be determined. By observing the actual choices, or revealed preferences, of the decision-makers, estimates of the parameters of the utility function can be obtained which can then be used for forecasting.

Because disaggregate models are estimated using observations of individual travel behavior, they have several distinct advantages over aggregate travel demand models. These advantages include the following:

- Disaggregate models, not being tied to any particular zonal system, can be used at any geographical level; i.e., they can be aggregated up to any level and once calibrated are applicable for both areawide and sub-regional planning.

- Because disaggregate models are behavioral rather than correlative, they are more easily transferred from one situation or area to another. This behavioral property attributed to disaggregate models has been sustained by recent examples of geographic and temporal transferability (Atherton, 1975; Cambridge Systematics, 1975).

- Disaggregate models make efficient use of the large base of home-interview surveys which are typically available in transportation planning studies. Several studies (Fleet and Robertson, 1968; McCarthy, 1969) have shown that the aggregation of data at the zonal level eliminates more than half the total data variability.

The efforts of transportation planners to develop more behavioral models at the disaggregate level have also led to a new perspective in examining how the complex web of transportation decisions made by travelers is structured. Earliest disaggregate models typically took as given the basic structure of the UTPS sequence: land use, auto ownership, trip generation, trip distribution, modal split and assignment. Thus disaggregate models developed by Warner (1962), Lisco (1967), Lave (1969) and others simply took one aspect of the UTPS modal split and replaced the traditional aggregate model with a disaggregate behavioral one. However, the UTPS sequence has virtually no behavioral foundation; travelers or households simply do not make one decision after another in a simple sequential fashion.

A general rethinking of a more realistic decision structure led to a far more credible theory, termed the choice hierarchy, eg. (Ben-Akiva, 1973). The choice hierarchy distinguishes between two groups of decisions. The first class, termed mobility choices, consists essentially of the long-run transportation-related decisions which households make. These choices include employment location, residential location, housing and automobile ownership. Such decisions are not generally made on a daily or weekly basis. Instead, they are made relatively infrequently. In addition, mode-to-work is included, since a trip made every workday is likely to be considered simultaneously with any change in the other decisions.

The second class of decisions, termed travel choices, includes the choices made by the household members with respect to non-work trips. Examples of travel choices include frequency, mode, destination, time of day, and routes for shopping, recreational, social and other non-work travel purposes. These choices are of a more short-run nature and can be altered rather frequently. Furthermore, it is hypothesized that the particular non-work trips a household makes are not re-evaluated jointly with the mobility choices.

Within each of these two groups of decisions the choices are highly interdependent. A household's choice of residential location should be viewed as an element of the mobility decision or, in other words, as made jointly with all other mobility choices. In the same manner, the choice of travel mode for a shopping trip, for example, should be viewed as an element of a shopping travel decision. The travel choices are assumed to be directly conditioned by the mobility choices. The outcome of the mobility choice determines the options available to the household for the travel choices. Thus, mobility and travel decisions

are made hierarchically, the latter conditioned on the former.

The structure of this postulated hierarchy is depicted in Figure 2-4. Each block represents a distinct model for a related group of choices; however, within each block the choices are made by a joint decision process. By this, it is meant that the household considers all relevant combinations of the various choices and evaluates each available combination as a direct alternative. This allows the household to consider the full range of possible trade-offs. For example, the household may choose to live in the downtown area and own zero or one autos, or it may select a suburban dwelling with two cars. Similarly, in making its travel choices a household may trade-off the costs and benefits of traveling to shop in a small neighborhood store against those of using transit to a central business district store. This choice simulation is termed as block conditional; the blocks or mobility and travel choices as single units have a conditional structure, while each block by itself has a joint structure.*

The choice hierarchy can be translated into the terms of disaggregate choice models by considering the joint probability of a mobility choice and a travel pattern choice, denoted as MO and TP, respectively, being selected out of a set of possible mobility and travel-choice combinations. First, the household makes long-term decisions by a process modelled by P(MO), the probability of selecting each mobility choice alternative. Then, the household makes travel choices conditional on MO by a process modelled as P(TP/MO)--i.e., the probability of selecting TP conditional on the selection of MO.

Using both these models, the total joint probability can be derived by using the simple rules of probability. Thus,

$$P(MP,TP) = P(MO) \cdot P(TP|MO).$$

Obviously, the proposed choice hierarchy does not apply to every household. Some households may, for example, not make any work trips; for them, the work trip decision is irrelevant. Other households may

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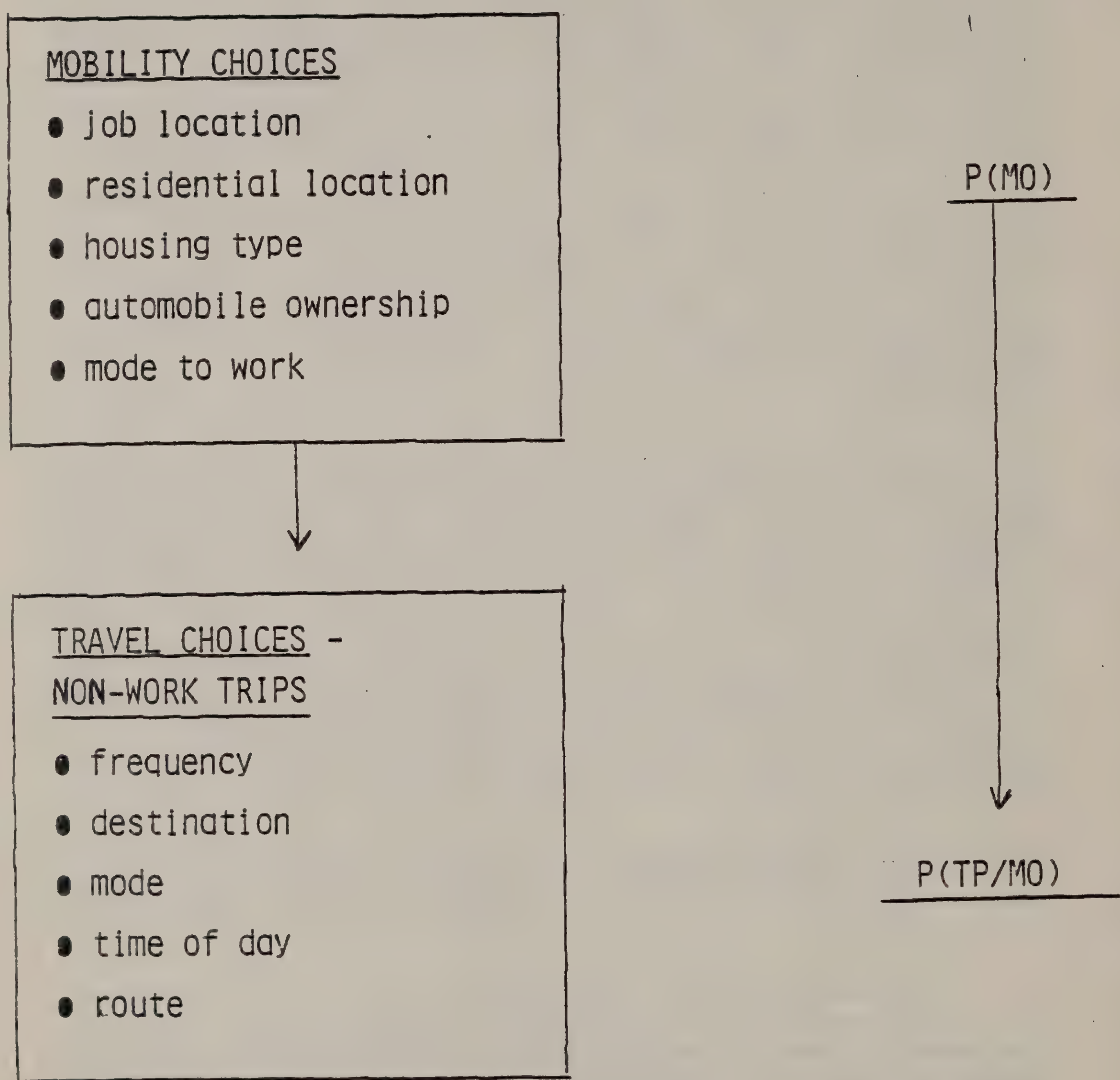
*This hierarchy has a direct analogy in classical economic utility theory in terms of "utility trees," developed by Strotz (1957 and 1959) to justify consumer demand models which consider limited subsets of the entire set of possible consumer goods.



MOBILITY AND TRAVEL MODELLING STRUCTURE

FIGURE 2-4

have no licensed drivers, and they therefore never choose to own autos. Nevertheless, if some care is exercised in defining the sub-population being modelled, the choice hierarchy is a useful conceptual base upon which more behavioral travel forecasting models can be built.

Almost all of the more recent transportation modelling efforts have relied on the same probabilistic choice model: the multinomial logit.*

The logic model has some distinct shortcomings (see Tversky, 1972). However, logit has the following advantages over some alternative probabilistic choice models.

- It is analytically tractable, and can be estimated using available computer programs without prohibitively high computational requirements.
- It provides a great deal of flexibility in defining the set of alternatives and in specifying the explanatory variables of the utility functions.
- It has been successfully applied to model a large number of varied choice situations, both in transportation planning and marketing and in other consumer behavior processes.
- The logit function mirrors the shape of a traveler's expected response to a causal variable, and can be derived from the concepts of choice and utility theory.

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*The analytic details of the multinomial logit are described by McFadden (1973) or Ben-Akiva (1973). In simple terms, the model postulates:

$$P_t(i:A_t) = \frac{e^{V_{it}}}{\sum_{j \varepsilon A_t} e^{V_{it}}}$$

Where: $P_t(i:A_t)$ is the probability of decision-maker t selecting alternative i from the set of available alternatives, A_t;

V_{it} is the indirect utility of alternative i, a function of the attributes of the alternative and the characteristics of the decision-maker t.

The function V_{it} is typically assumed linear in its parameters and is generally estimated using the maximum likelihood technique.

The first disaggregate modelling study to consider some set of travel decisions other than simply mode choice was performed by Charles River Associates (1972). In this pilot study with very small data samples, a sequence of choice models for shopping trips was developed. This sequence was closely tied, conceptually, to the UTPS, and was as follows: trip frequency, destination, time of day and, finally, mode.

In another small-scale study, Ben-Akiva (1973) abandoned the sequential roots of the UTPS in the development of shopping trip models which considered mode and destination jointly; i.e., the mode and destination decisions of travelers were assumed to be inseparable in nature. Adler (1975) extended this work using much larger data samples to include trip frequency (i.e., whether or not to travel on a given day) in the joint modal structure, and Lerman and Ben-Akiva (1979) developed such models for other non-work-trip purposes.

There have also been efforts to apply choice models to mobility decisions other than the simple work mode choice problem. Aldana (1971) developed a series of models which assumed the following sequence: residential location, automobile ownership, then mode.

Ben-Akiva and Lerman (1975) developed the first joint disaggregate model for a subset of the mobility choices: automobile ownership of the household and mode to work of its primary worker. This study developed separate models for different market segments, i.e., separate socioeconomic groups with different preferences. Nine distinct segments defined by household life cycle and primary worker occupation were used. One of these market segments was defined for all households without any full-time workers. For this market segment, mode to work is not a relevant choice and therefore the general choice hierarchy needs to be modified.

3.0 THE DEMAND FOR TRAVEL

3.1 DEMAND FOR TRAVEL

The complexity of travel demand is apparent from the way in which one characterizes a trip; e.g., by its origin, its destination, the time of day when it is made, the mode of travel, the route, and the trip purpose.

Trip ends are spatially disaggregated; a trip is made from a specific origin to a specific destination. For a work trip the origin and the destination are fixed by the choices of the residential location of the household and the trip-maker's place of work. While one end of most other trips is fixed by the location of the trip-maker's home, there is usually a choice among several destinations. For example, a shopping trip can be made to either a local grocer or to a more distant shopping center.

The time of day when a trip is made can be influenced by the effects of peak periods and the congestion usually associated with travel during that period. For the majority of workers, starting and finishing times are not totally within their control, yet they can still decide to arrive early and leave late in order to avoid traveling during the peak period. Some degree of freedom is also provided by employers operating flexible working time systems (flex time). Optional activities are less constrained, and the consumer can normally exercise a reasonable degree of choice as to when he makes a trip to and from such activities.

In the Boston metropolitan area a traveler has a choice between private car, public transport (i.e., bus, train or rapid transit), bicycle and walking. A traveler can also sometimes choose between driving his own car, being driven, or participating in a carpool. Some travelers can also choose to make a single trip utilizing a sequence of different modes. A typical example of such a complex trip is the commuter who drives his car to a suburban railway station, parks the car, takes the train to the city center, and finally travels by bus to his place of work. In dense networks, the traveler can usually choose between several alternative routes, especially when traveling by car, or bicycle ~~or moped~~. Speed, congestion, distance, safety, driving comfort and reliability can all affect the choice of route.

For a given trip the traveler is faced with the following set of choices:

- choice of destination
- choice of time of day
- choice of mode, and
- choice of route.

In addition, a potential trip-maker has to decide whether or not to make a trip, or how often to make a trip for a given trip purpose. For example, families can shop with different frequencies: every day, twice a week, once a week, etc.

A trip is rarely, if ever, made for its own sake, but for some purpose which can be served at its destination, in order to gain some benefit or utility. Thus the classification of trip purpose does not represent an inherent characteristic of the trip itself, but rather stems from the recognition that the demand for trips is a derived demand, as pointed out in Oi and Shuldiner (1962) and Kraft and Wohl (1967). Therefore, trip-makers' behavior need not be the same for different trip purposes.

Given the normal practice of defining classes of trip purpose, such as work, firm's business, recreation, school, social, shopping, and personal business, it is reasonable to hypothesize that there is negligible substitution between trips for different purposes unless the corresponding activities undertaken at the trip destination can themselves be considered as substitutes for each other.

A trip from home to an activity is usually accompanied by a trip from that activity back home, forming a simple tour, or chain, of two trips; under more complex circumstances, more than one activity can be undertaken, or satisfied, during the course of a complex tour composed of three or more trips. In a complex tour the trips to and from each destination are generally interdependent, since decisions made with regard to the first leg both constrain and influence the decisions made with regard to the remaining legs, and the alternatives available for those remaining legs can be expected to influence the decisions made concerning the first leg. For example, someone who goes from his home to shop by car is highly likely also to return home by car. If he chooses to make another stop on this tour for shopping, or any other activity, his choice of the two destinations can not be considered as being

independent of each other, nor can his choice of mode; he has probably considered all elements of his travel decision prior to starting out on his trip.

Simple tours--e.g., home-work-home, home-shop-home, etc.--have in most cases two identical legs, and therefore pose no additional problems for modeling. In the few cases where the mode of travel for the two legs is not the same--e.g., going shopping by bus and returning by taxi--the relatively few possible combinations of modes could be handled by defining them as separate alternatives. However, for some complex tours the dimensions of choice--that is, the number of alternative trip options--can be extremely large. It should be noted, however, that the majority of urban trips are elements of a simple two-trip chain, as pointed out by Adler (1977).

3.2 CHOICE THEORY

Models describing consumer behavior are based on the principle of utility maximization subject to resource constraints--that is, they are based on the assumption that the consumer will endeavor to maximize the benefits he can obtain within the limitations of the available resources, usually time and money. This is an approach of economic consumer theory that assumes a selection of quantities from a set of commodities and the quantities demanded are treated as continuous variables. Choice theories, on the other hand, consider a selection from a finite set of mutually exclusive and exhaustive alternatives.

In the classical economic theory demand approach with a continuum of alternatives, a deterministic behavior is assumed, except for a random disturbance added in estimation to explain variation among individuals and to account for factors not incorporated. In choice theory, with qualitative or discrete alternatives, a probabilistic behavior is assumed which explains observations of different choices for the same set of observed independent variables.

The travel demand of a single consumer is more appropriately viewed in a choice context rather than in the traditional demand analysis framework. Since travel choice can better be described as a probabilistic choice from a discrete set of mutually exclusive and exhaustive alternatives than as the selection of a quantity of a commodity, the travel demand models developed in this study rely on probabilistic choice theories.*

*Choice theories are reviewed in Luce and Suppes (1965).

The consumer is visualized as selecting that alternative which maximizes his utility. The probabilistic behavior mechanism is a result of the assumption that the utilities of the alternatives are not certain, but are random variables determined by a specific distribution.

If we denote the utility of alternative i to consumer t as U_{it}, the choice probability of alternative i is therefore:

$$P(i:A_t) = \text{Prob}\left[U_{it} \geq U_{jt}, \forall J \in A_t\right] \tag{3.1}$$

where A_t is the set of alternative choices available to consumer t.

This means that the probability of choosing one alternative out of the complete set of possible alternatives, $P(I:A_t)$, equals the probability of the utility of that alternative being greater or equal to the utility of any of the other alternatives in the full range of alternatives. The utilities are essentially indirect utility functions which are defined in theory as the maximum level of utility for given prices and income. In other words, the utility U_{it} is a function of the variables which characterize alternative i, denoted as X_i, and of the socioeconomic variables describing the consumer t, denoted as S_t. Thus,

$$U_{it} = U_i(X_i, S_t) \tag{3.2}$$

A simple example of such a function is a utility function for a mode choice model composed only of travel time and car availability. The travel time can be expected to vary between alternatives, while car availability remains constant for a given person. The travel time would thus explain the choice of mode for a given person, and the car availability would explain differences in mode choice between persons having an identical set of levels of service for each available mode but different levels of car availability. The set of alternatives, A_t, is both mutually exclusive and exhaustive such that one, and only one, alternative is chosen.

The deterministic equivalent of this theory is simply a comparison of all alternatives available and the selection of that alternative having the highest utility.

The mathematical form of the choice model is determined from the assumptions about the distribution of the utilities. The coefficients of each of the variables comprising the utility functions are estimated over a cross-section of consumers using observations of the

actual choices made and determination (or observation) of the alternatives available but not selected. Therefore, the observed dependent variable has a value of zero when an alternative was not selected and of one when an alternative was selected. When applied to forecasts, the model will give the probability of each of the alternatives being selected; the sum of these probabilities must clearly equal 1.0.

3.3 TRAVEL CHOICES

Given that for the individual trip maker the decision to make a trip for a given trip purpose consists of several choices (choice of trip frequency, choice of destination, choice of time of day, choice of mode of travel, and choice of route), we need to predict the volume of trips, V_{idhmr}, from origin i to destination d, during time period h, using mode m, and via route r. Or in a probabilistic choice approach, we are interested in predicting the following joint probability:

$$P(f,d,h,m,r,:FDHMR_t).$$

This is defined as the probability that individual t will decide to make a trip with frequency f, to destination d, during the time of day h, using mode m, and via route r, from the full set of available alternatives of frequencies (F), destinations (D), times of day (T), modes (M), and routes (R), available to individual (t): i.e., $FDHMR_t$. In general the utility U_{fdhmrt} of a given trip can be denoted thus:

$$U_{fdhmrt} = U_{fdhmr}(Z_{fdhmrt}) \tag{3.3}$$

$$\text{where } Z_{fdhmrt} = L,E,S \tag{3.4}$$

L = level-of-service characteristics, such as time, travel cost, safety, comfort, etc.

E = spatial opportunity characteristics describing the availability and the intensities of the activities for which a trip is made - e.g., employment, land use, etc.

S = socioeconomic characteristics of the trip-maker, such as income, education, etc.

It should be noted that L and E both represent attributes of the alternatives; these can be more generally denoted by X.

For a mode choice model in which, in the interests of simplicity, we consider only one mode (m), destination (d), and frequency (f), the utility function can be written thus:

$$U_{mt} = U_m\left[X_{m|d,f}, S_t\right] \tag{3.5}$$

where $X_{m|d,f}$ means that the values of the variables for mode m are for a given destination and frequency.

This form of model is described as a conditional model, in that it is applied to the estimation of mode choice given that, or conditional upon, the frequency and destination being pre-determined. For a simultaneous mode and destination choice model, the utility function is written as follows:

$$U_{mdt} = U_{md}\left[X_{md|f}, S_t\right] \tag{3.6}$$

In this case the selection of destination and mode is conditional upon a trip being made or, more precisely, upon the trip frequency, f.

Clearly, the set of alternatives available to any given individual varies between choice situations, and thus the set of alternatives considered for any given person will be different for different models. In a mode choice model, which assumes the destination choice as given, the set of alternatives is all the possible modes to the given destination. In a simultaneous destination and mode choice model the set of alternatives will include all the possible combinations of modes and destinations for a given trip purpose. The set of alternatives may also differ for otherwise identical persons at different locations. For example, the private car is not a feasible alternative for a person from a household with no cars, and thus, for people from such a household, a shopping destination which can only be feasibly reached by car is not a valid alternative destination.

3.4 THE LOGIT MODEL

3.4.1 The Model

In the previous section the demand for travel was characterized as a choice among a set of discrete, or qualitative, alternatives, just as the total amount of travel can be regarded as a choice among different trip-making frequencies. Since a potential traveler can decide not to make a trip at all, a no-trip

alternative must also be included in the set of alternatives confronting him. Consequently, for any given traveler, one, and only one, alternative can be chosen from this set, but the set of alternatives can be assumed to be different for different travelers.

The focus is on the probability of each alternative being chosen; thus the aggregate measures the share of each alternative. Clearly, the probability, or the share, of any alternative must lie between zero and one (inclusive) and the sum of the probabilities (shares) of all alternatives must equal unity.

The choice model used throughout this study is the multinomial logit model. Other choice models which might be considered to be superior from a theoretical point of view, such as a multiple probit model, are more complex, and it is doubtful whether the added expense of more sophisticated choice models is justified (de Donnea, 1971; Ben-Akiva, 1973).

The logit model is written as follows:

$$P(i:A_t) = \frac{e^{U_{it}}}{\sum_{j \varepsilon A} e^{U_{jt}}} \qquad (3.7)$$

where t = a behavioral unit (in the case of this study, a person)

= 1, 2,..., T

A_t = the set of relevant alternatives for behavioral unit t

$P(i:A_t)$ = the probability that behavioral unit t will choose alternative i out of the set A_t

U_{it} = the utility of alternative i to behavioral unit t.

The utility U_{it} is a function of the characteristics of alternative i (or generalized "prices") and the socioeconomic characteristics of behavioral unit t (or "income"). The characteristics of the alternatives could include the travel time to the alternative, the parking charge or congestion at that alternative, or some measure of its attractiveness, such as the number of employees. The socioeconomic characteristics include income and other variables, such as family

life cycle, education, etc., which can account for differences in tastes, etc.

In essence this is thus an indirect utility function which is defined as a function of prices and income. Alternatively, it can be viewed as an expenditure function which is a function of prices. Hence, the function U_{it} can be expressed in the form:

$$U_{it} = U_i(X_i, S_t) \tag{3.8}$$

where X_i = a vector of characteristics of alternative i

S_t = a vector of socioeconomic characteristics of behavioral unit t.

It is assumed that the function U_{it} is a linear function in the parameters:

$$U_{it} = X_{it}' = \sum_{k=1}^{K} X_{itk}\theta_k \tag{3.9}$$

where X_{it} = a Kxl vector of finite functions which are constructed from the various X and S variables and are diferent from one alternative to the other (this definition is explained in detail in the following section)

$= (X_{it1}, X_{it2}, \ldots, X_{itK})$

θ = a Kxl vector of coefficients to be estimated for each model

$= (\theta_1, \theta_2, \ldots, \theta_K)$

This assumption can be justified if the U's are interpreted as the combination of equivalent costs for the different alternatives; i.e., that the coefficients reflect the conversion factors from the units of the particular parameter to monetary units. For example, the coefficient of travel time would reflect value of time in dollars per hour, hence converting the time term to equivalent dollars. This assumption is required since the available estimation program requires linearity in the parameters.

Equation (3.9) can now be expressed as follows:

$$P(i:A_t) = \frac{e^{X_{it}'\theta}}{\sum_{j\varepsilon A_t} e^{X_{jt}'\theta}} \tag{3.10}$$

3.4.2 The Variables of the Model

A variable in X_{it}, say, X_{itk}, can be specified either as a generic variable or as an alternative specific variable. If the variable X_{itk} appears only in the utility function of alternative i, then it has a value of 0 for all other alternatives; that is:

$$X_{jtk} = 0, \; \forall j \neq i \varepsilon A_t \tag{3.11}$$

This variable is thus specific to i and is termed an alternative i specific variable.

If the variable X_{itk} appears in the utility functions of all the alternatives, it is termed a generic variable. Consider, for example, the variable of travel time in a mode choice model; if the travel times by the different modes are assumed to have a common coefficient, or weighting, in their respective utility functions, then travel time is specified as a generic variable. The variable X_{itk} will then take the value of travel time by mode m. If on the other hand the coefficients of travel time are mode- or alternative-specific, then a series of mode-specific variables can be introduced. In this case it is assumed, a priori, that the weight of travel time in the respective utility functions for each mode is not constant across all modes. The mode m travel time variable will then be specified as follows:

$$X_{itk} = \begin{cases} \text{travel time by mode m,} & \text{for } i = m \\ 0, & \text{for } i \neq m \end{cases}$$

and if there are M alternative modes, there will be a total of M travel time variables and coefficients. If all the variables in the model are generic, then the model can be described as an abstract-alternative model (Quandt and Baumol, 1966; Charles River Associates, 1972). Since there are no variables present in such a model which relate to any specific alternative, but only variables which relate to characteristics common to all the alternatives, an abstract alternative model can be applied for forecasting purposes to situations substantially different from those used for

model estimation. An abstract-alternative model is thus highly suited to the evaluation of systems not yet in use.

Alternative-specific variables are relevant only when there is direct correspondence among the alternatives availabe to different individuals--e.g., alternative modes. The specification of all the variables in a model as alternative-specific implies that the utility functions are alternative-specific as well.

When there is little correspondence between the sets of alternatives available to different individuals, one can use only generic variables. For example, if the set of alternative shopping destinations at one origin are entirely different from the destination set at a different origin, one can say that there is no correspondence between the sets of alternatives, and thus those alternatives can only be described through the use of generic variables. Another example is that of alternative routes which are inevitably different for different trips.

If a generic variable takes the same value for all alternatives ($j \varepsilon A$) for all individuals ($t \varepsilon T$)--i.e., for some k: X_{itk}, $\forall\ j \varepsilon A$, $\forall\ t \varepsilon T$--then it will have no effect on the model, due to the linear specification. In other words, the coefficient θ_k is not identified. For example, if the variable X_{itk} is income, then the same term is used to multiply the numerator and each member of the sum in the denominator, and it will thus cancel out. This means that all the variables in X_{it} must have alternative-specific values. This is not to be confused with alternative-specific variables; the reference here is to the value a variable assumes. Hence, the socioeconomic characteristics S_t can enter the model only when they are transformed to have alternative-specific values. This can be done in two ways:

1. Combining them with the X_i variables:

   $$X_{itk} = g^k(X_i, S_t)$$

   where g^k is a finite function (e.g., price divided by income). The function $g^k(X_i, S_t)$ has an alternative-specific value, and can be used to define either a generic or an alternative-specific variable.

2. Introducing a series of alternative-specific variables, each one of which takes the value of the socioeconomic variable for a certain alternative and is otherwise zero. For example, an income variable for alternative one which equals

income for alternative one and zero for all other alternatives.

Furthermore, for a given socioeconomic variable, such as income, we can introduce only N-1 alternative-specific variables where N is the total number of alternatives. An attempt to estimate a model with N alternative-specific variables with the same value (e.g., income) will fail due to perfect "collinearity" (i.e., the likelihood function will have a ridge for multiples of θ). If we introduce such variables for the first N-1 alternatives, then the coefficient estimate of an alternative i specific variable is the difference between the actual coefficient of alternative i variable and that of alternative N variable. This can be observed from rewriting equation (3.10) as follows:

$$P(i:A) = \frac{1}{\sum_{j \varepsilon A_t} e^{(X_{jt} - X_{it})'\theta}} \tag{3.12}$$

If the model was originally written with N alternative-specific variables with the same value, the exponents in the sum will include differences of the original coefficients; thus only N-1 differences can be identified. It is apparent that this also applies to dummy variables which take that value of 1 and represent a "pure alternative effect," e.g., a mode-specific constant.

3.4.3 Elasticity of the Logit Model

3.4.3.1 Disaggregate Elasticity

For the logit model defined in (3.10) the disaggregate elasticity is described as:

$E^{P(i:A_t)}_{X_{itk}}$ ...direct elasticity

$E^{P(i:A_t)}_{X_{jkt}}$ ...cross-elasticity

or, in more complete form:

$$E^{P(i:A_t)}_{X_{jtk}} = \frac{\partial P(i:A_t)}{\partial X_{itk}} \cdot \frac{X_{itk}}{P(i:A_t)} \tag{3.13}$$

$$E^{P(i:A_t)}_{X_{jtk}} = \frac{P(i:A_t)}{X_{jtk}} \cdot \frac{X_{jtk}}{P(i:A_t)} \tag{3.14}$$

This results in:

$$E^{P(i:A_t)}_{X_{itk}} = \left[1 - P(i:A_t)\right] \Theta_k \cdot X_{itk} \tag{3.15}$$

$$E^{P(i:A_t)}_{X_{jtk}} = \left[-P(j:A_t)\right] \Theta_d \cdot X_{jtk} \tag{3.16}$$

General expressions for elasticities:

$$E^{P(i:A_t)}_{X_{jtk}} = \left[\delta_{ij} - P(j:A_t)\right] \Theta_d \cdot X_{jtk} \tag{3.17}$$

δ_{ij}....Cronecker symbol

Note: if variable X_{itk} enters the model as X_{itk}, then the elasticities are as given above divided by X_{itk}.

The direct elasticity varies from zero when the choice probability is one, to $\Theta_k X_{itk}$ when the choice probability is zero. If variable enters the model in a logarithmic form, the upper limit of the elasticity will be constant and equal to the coefficient Θ_k.

The cross-elasticity is dependent only on values related to alternative j and not to alternative i for which the cross-elasticity is computed. This means that the cross-elasticities of all alternatives with respect to an attribute of alternative j are equal.

3.4.3.2 Aggregate Elasticity

For a ranked alternative, an aggregate elasticity can be defined. It is defined with respect to the average choice probability as:

$$P_i = \frac{\sum_{t=1} P(i:A_t)}{T} \tag{3.18}$$

If $X_{jtk} = X_{jk} \; \forall \; t=1,\ldots,T$

then

$$E^{\bar{P}_i}_{X_{ik}} = \frac{\partial \bar{P}_i}{\partial X_{jk}} \cdot \frac{X_{jk}}{\bar{P}_i}$$

$$= \frac{\sum_{t=1}^{T} P(i:A_t) \, E^{P(i:A_t)}_{X_{jk}}}{\sum_{t=1}^{T} P(i:A_t)} \qquad (3.19)$$

The aggregate elasiticity is, in this case, a weighted sum of the individual elasticities using the individual probabilities as weights.

3.4.4 Estimation Technique

For a cross-section of behavioral units making a choice, one does not observe the probabilities, but only actual choices. Hence, with disaggregate data the observed dependent variable takes a value of either 0 or 1. The independent variables are continuous and/or discrete. With observed 0,1 dependent variables, the maximum likelihood method is used to estimate the model coefficients. The estimator of the θ's of the logit model as in equation (3.7) and its properties are described by McFadden (1968).

If groups of behavioral units are aggregated according to socioeconomic categories or geographic location, and the groups are used as the observation units, then the observed dependent variable is a share with a value between 0 and 1. With grouped data both a maximum likelihood and ordinary least squares techniques can be used. The ordinary least squares technique is based on the linearization of the model by dividing the probability of each alternative by a "base" alternative and taking logs. The estimated coefficients are therefore sensitive to the choice of a "base" alternative, except for binary choice (see, for example, McLynn and Woronka, 1969). A maximum likelihood estimator with aggregate data has not been used, but in principle it is a simple extension of the disaggregate estimator.

The likelihood function of a disaggregate sample is written as follows:

$$L = \prod_{t=1}^{T} \prod_{i \varepsilon A_t} P(i:A_t)^{g_{it}} \qquad (3.20)$$

where T is the number of observations and g_{it} equals 1 if alternative i was chosen in observation t, and 0 otherwise.

Taking the logarithm of both sides, 3.20 reads:

$$\ln L = L^* = \sum_{t=1}^{T} \sum_{i \varepsilon A_t} g_{it} \cdot \ln P(i:A_t) \qquad (3.21)$$

Substituting equation (3.7) for $P(i:A_t)$, the first-order conditions are as follows:

$$\frac{\delta L^*}{\delta \Theta_k} = \sum_{t=1}^{T} \sum_{i \varepsilon A_t} \left[g_{it} - P(i:A_t)\right] \cdot X_{itk} = 0 \qquad (3.22)$$

for k=1,...,K.

This is explained in greater detail by McFadden (1968). The K equations in (3.22) are non-linear and their solution requires an iterative procedure. In this study we use the Newton-Raphson method. The estimation computer program used was developed by C.F. Minski. He showed that, except under very specific conditions in the data, the maximum of L* obtained from (3.22) is unique. This estimator has optimal asymptotic properties; as the number of observations increases, it can be shown that the estimator approaches "optimality," i.e. approaches minimum variance in the estimate of each coefficient. The asymptotic variance covariance matrix is the inverse of the matrix of second derivatives of L* multiplied by minus one (Theil, 1971).

It should be noted, however, that since probabilities are not observed, it will be misleading to compare the computed probabilities with the g_{it} variables: if one assumes that the actual choice is made with a probability and not with certainty, as the g_{it} variables would indicate. Therefore, a "goodness of fit" measure, such as R^2 in ordinary least squares, which is based on estimated residuals, is not appropriate. In addition, a comparison of a sum of probabilities for a given alternative with the total number of observations in which this alternative was chosen is

misleading under the following conditions. If the set of variables includes an alternative specific constant:

$$X_{tjk} = \begin{cases} \text{constant}, & \text{for } j = i \\ 0, & \text{for } j \neq i \end{cases} \tag{3.23}$$

then from the first order conditions, equation (3.22), the following always holds:

$$\sum_{t=1}^{T} g_{it} = \sum_{t=1}^{T} P(i:A_t) \tag{3.24}$$

Thus, for a disaggregate logit model, because residuals cannot be estimated, there is no R^2 statistic which will indicate how well the model "fits" the data. However, it is possible to define a measure analogous to R^2 which is based on the value of the ln likelihood function and can be used to compare alternative models, as follows:

$$\rho^2 = 1 - \frac{L^*(\theta)}{L^*(0)} \tag{3.25}$$

where $L^*(\theta)$ is the value of L^* for the vector of estimated coefficients and $L^*(0)$ is the value of L^* for $\theta=0$.

Since the likelihood function is the product of probabilities, and the probabilities are always between zero and one, the likelihood function must be between zero and one, and the ln of the likelihood function must always be negative. Therefore, the process of maximizing likelihood is to raise $L^*(\theta)$ from a large negative number, and $L^*(0)$ to as close to zero as possible. Thus, p^2 is equal to the ratio of the explained ln likelihood over the total ln likelihood, and it lies between 0 and 1.

This measure suffers from the same deficiencies as R^2. In particular, it does not take account of the degrees of freedom. Adjusting for the degrees of freedom, we get:

$$\bar{\rho}^2 = 1 - \frac{L^*(\theta) \Big/ \sum_{t=1}^{T} (J_t - 1) - K}{L^*(0) \Big/ \sum_{t=1}^{T} (J_t - 1)} \tag{3.26}$$

where J_t is the number of alternatives in A_t and K is the total number of variables specified.

Setting $\theta=0$ amounts to an assumption of equally likely alternatives. When all utility functions go to zero the probability of any alternative goes to $1/J_t$, since $e^0=1$. However, for ranked alternatives, one can compute a version of $L^*(0)$ that takes into account pure alternative effects, i.e., that sets initial estimates of the probabilities equal to the observed frequencies using the alternative-specific constants.

4.0 DATA

4.1 DATA REQUIREMENTS

4.1.1 Introduction

Estimation procedures associated with disaggregate travel demand models call for special data structures. These structures differ substantially from ones required by aggregate travel demand models because the travel choices of individual households (behavioral units) and not the behavior of traffic zones is being modeled. Theoretically, disaggregate demand models are based on complete information on all the activity and transportation system characteristics with which a behavioral unit is surrounded, and on the socioeconomic characteristics of that behavioral unit. Descriptive information on available travel and destination alternatives, coupled with knowledge of actual travel activities (choice mode) of a behavioral unit, is the starting point for the travel choice process modeling described in Chapter 3. Unfortunately, very few data sets exist that satisfy the requirements imposed by the theory of disaggregate models. Although all information should be collected on the behavioral unit level, the required information can be reconstructed from zonal data available from the traditional metropolitan area data bases. Furthermore, most of the disaggregate models estimated with theoretically sound data bases do not differ significantly from models estimated with more conventional data bases.

The data required for the estimation of the two models used in the study (a) a mode choice model for work trips and (b) a destination frequency and mode choice model for shopping trips can be divided into four groups of information on households and their choices: (1) valid alternatives, (2) socioeconomic data, (3) level of service data and (4) shopping center attraction data. Each of these types of data will be described in the following sections.

4.1.2 Valid Alternative

The term "valid alternative" refers to a procedure for minimizing the volume of data being handled by considering only valid travel alternatives, e.g., household and personal socioeconomic data are examined to determine whether, on the basis of household auto ownership and possession of a driver's license, a car could be

regarded as an alternative mode. If no car is owned, it is reasonable to assume that driving a car is not a valid alternative. Furthermore, if a car is available within the household, but an individual does not own a valid driver's license, then car is not considered as a valid alternative.

Other stipulations on valid alternatives relate to walk access, bus usage, and shopping centers. Walk access to train stations was considered a valid alternative only if the station destination was a mile or less away from the trip-maker's origin. Bus was not considered a valid alternative for work trips of 30 minutes or greater duration, since no such trips by bus were observed. Bus was also not considered a valid alternative for shopping trips unless there were at least two stops between the boarding and alighting stops. The number of valid shopping center alternatives was limited to two choices for each individual. One alternative was the Boston CBD and the other was the closest regional shopping center.

4.1.3 Socioeconomic Data

Of the available socioeconomic data, the following were utilized in the models estimated:

1) Income - household income

2) Car Availability - cars per driver, i.e., the ratio of cars in a household to the number of persons with a license

3) Occupation - a classification of occupations into:
   a) professionals, managers and executives
   b) all others

4) Household size

4.1.3.1 Use of the Home Interview Survey

The 1963 Home Interview Survey was a major source of socioeconomic data for this study. The travel information on the Home Interview Survey (HIS) is recorded for every person in the household of age five or older, and includes travel information (purpose, mode, time of day) for each separate trip link.

Socioeconomic information is collected both for the household as a whole and for each individual over 18. The household level data include household size, household income, the type and number of automobiles owned, and the education of the head of the household. Information which is collected for each individual includes age, sex, occupational status, and workplace.

Two major difficulties might arise in the use of these data for estimating a disaggregate choice model. The first difficulty arises from a lack of complete information. There are, in the survey sample, a large number of households for which the surveyor indicated that travel information was missing. Eliminating these observations probably biases the sample away from larger households or those that are engaged in a large amount of travel (although the surveyors were instructed to personally contact traveling members of the household in order to obtain accurate travel summaries, it is expected that most of that information was not obtained). However, including observations with missing travel information in the estimation sample could lead, for example, to misclassification with respect to frequency of travel. In the model estimation for the task in hand, the bias from excluding incomplete observations can be assumed to be less severe than the one which might result from the misclassification of those households.

The second difficulty with the HIS is that "walk" links were not recorded, except for the case of the first link to work. This presents a problem in interpreting round trips which appear, from the recorded date, to be incomplete. For some of the trips, it might be clear that there is a coding mistake, but for others there is no way of completing the round trip description. Also, since walk, in the HIS, is defined to include motorcycle, bicycle, and other miscellaneous modes, there is no way of determining the actual mode for the "walk" links to work (or, for that matter, any of the links which were excluded from round trip descriptions due to their having been labeled "walk").

4.1.3.2 Generation of Missing Data

In the cases where household data on income and car availability was missing, an algorithm was used to generate sample observations. This algorithm uses a beta and gamma distribution to represent income and auto ownership respectively and applies these distributions to income and auto ownership data from the 1970 Census and 1963 Home Interview Survey. These two distributions were chosen because they have the shape one would equate with empirically observed distributions of income and household auto ownership and are defined with only two parameters.

The algorithm is defined as follows:

1) Generate income and the number of cars per household random sample with i zones

2) Generate income and the number of cars per household random sample for the zone i.

3) Generate income for the household i in the zone

4) Adjust means and variances in the zone i. Let

PD ...services price deflator for the years 1970-1975

$m_{1,1975,I} = m_{1,I}$ ...mean income in 1975

$m_{1,1970,I}$ ...mean income in 1970

$m_{2,1975,I} = m_{2,I}$ ...variance of income in 1975

$m_{2,1970,I}$ ...variance of income in 1970

$m_{1,I} = m_{2,1975,I} = PD * m_{1,1970}$

$m_{2,I} = m_{2,1975,I} = PD^2 * m_{2,1970}$

5) Normalize $m_{1,1}$ and $m_{2,1}$.

6) Compute parameters r and t of B-distribution.

$$r = m_{1,I} \left(\frac{m_{1,I}(1-m_{1,I})}{m_{2,I}} - 1\right)$$

$$t = \frac{r}{m_{1,I}}$$

Adjust r and t so that $2 \leq r \leq 4$ and $5 \leq t \leq 8$.

7) Check to see if distribution is skewed to the right. If it is, go to step three; if not, force it to be a normal distribution.

a. if $r < \frac{1}{2}t$, go to step #3

b. if $r \geq \frac{1}{2}t$, then $m_{1,I} = \frac{1}{2}$ (hence $r = \frac{1}{2}t$)

8) Finish mean income generation step in the zone i.

9) Start computing mean number of cars per household in the zone i.

10) Compute parameters k and ℓ of B-distriubtion.

$m_{1,c}$ ... mean number of cars per household in the zone

$m_{2,c}$ ... variance of the number of cars per household in the zone.

a.
$$\ell = \frac{m_{1,I}}{m_{2,j}}$$

$$k = \frac{m^2_{1,I}}{m_2}$$

b. Check if $\ell > 0$ and $k > 0$

- If yes, continue.
- If no, reject the zone. Flag the zone number. Continue to the next zone (reduce the number of zones).

11) Correlate means of income and the number of cars in households in the zone: set $x = \frac{t}{\ell}$ so that $.001 < x\ell \leq 6$.

12) Finish computing mean number of cars in the zone.

13) Start generating income and number of cars for desired number of households in the zone.

14) Generate random variable x.

a. Generate U_j and U_{j+1} (unit random variable)

b. Set $A = (U_j)^{1/r}$

Set $B = (U_{j+1})^{1/t}$

c. Check if $A+B \leq 1$

- If no, generate a new pair of random numbers.
- If yes , then (d.)

d. $X = (A)/(A+B)$

15) Compute income for the specific household I

$I = X * I_{max}$

16) Compute the number of cars for a specific household.

$F_c(\ell x)$ ... normalized cumulative distribution of the number of cars per household

6 ... maximum number of cars per household is A

3.03 ... empirical constant

NC ... number of cars per household

a. $Fc = \frac{G(k.ax)}{G(k)}$

b. NC - 6*3.03*Fc*X

17) Go back to step 13 to generate as many cases as necessary for each zone.

18) Go back to step 2 and repeat the process for all zones.

19) Finish the algorithm.

It should be noted that the B-distribution is valid over the range (0--one). Thus, one should normalize computations of the mean m_1 and the variance m_2 for income (divide actual with max income^1 and m_2 with max income^2 squared).

Note also that in some cases a randomly generated variable for B-distribution gets thrown out. This is done to avoid an otherwise extremely complicated scaling procedure.

4.1.4 Level-of-Service Data

Level-of-service data were required for each of the valid modes pertaining to each home-work chain in the sample. In practice this means obtaining data for up to three modes for each of the 411 observations.

The level-of-service information which is available for the Boston area is in the form of zone-to-zone networks for the origin-destination based data, and zonal vectors for origin-specific or destination-specific variables. Aside from the problems of reformatting the network data to suit the disaggregate modeling application, the level-of-service data set has intrinsically one major shortcoming: its basic aggregate orientation. For example, transit availability can be determined only on the zonal level, as opposed to being separately indicated for each household. Furthermore, this zonal-based availability can be calculated only by using an arbitrary cut-off distance for walk access to transit stations. Similarly, out-of-vehicle travel times are completely zonal based and are aggregated, from access time, wait time, and transfer time, into a single excess time variable.

The specific items of level-of-service information which can be extracted from the existing data sets are listed in the Figure 4-2. All of the information was compiled separately for the peak and off-peak to account for congestion effects in the peak period.

Network data were derived by manually locating each pair of home and work addresses on large-scale plans. Travel times and distances for cars were estimated using networks and travel-time tables prepared for CTPS and based

<u>Transit</u>

transit pointers:	indication of transit availability in the zone.

<u>Auto</u>

terminal times:	times required to start car and find a parking place at the origin or destination.
parking costs:	costs for parking while at work or for short term parking

ZONAL VECTOR DATA

FIGURE 4-1

<u>Transit</u>	
excess time:	access wait transfer
in vehicle time:	total time in vehicle
auto connector time:	time required to drive to the nearest transit stop
fare:	total fare computed on the 1963 fare schedule
<u>Auto</u>	
highway time:	total in vehicle travel time
highway distance:	length of the quickest route
highway cost:	computed by determining average speed over the route ⟶ per mile cost X distance

ZONE TO ZONE NETWORK DATA

FIGURE 4-2

on the 1963 Home Interview Survey. The speeds in the car networks were based on a journey-time study carried out by the MDPW.

The networks and matrices were based on a zonal system and therefore the individual values derived from the network had to be corrected to allow for the positive or negative difference between the location of the zone centroid and the individual address (home or work) for which data were being sought.

Since the type of car driven by car users, or available to those not driving was not known, an average cost for a typical family car was obtained from Hertz's 1978 annual report.

The survey data did not allow the identification of specific parking space locations for each individual destination. Instead, parking charges were adopted from average values given in a Boston CBD parking survey*. The average daily charge for public facilities of $2.50 was used as the parking charge for working trips. Areas of the Boston CBD with an actual charge of $2.50 to $3.49 are shown in Figure 4-3.

Waiting time for both train and bus was determined using the function shown in Figure 4-4. This role was empirically observed and first reported by Kulash**.

4.1.5 Shopping Center Attraction Data

The attraction data available for estimation of the shopping trips and social-recreational trips model is limited to zonal employment statistics and zonal land use data. Other information, such as floor space and gross revenues, is desirable; but, the available data is sufficient for the description of alternative destination choices.

4.1.6 Summary

Primary data sources included:

1) 1963 Home Interview Survey
2) 1970 Census

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* Wilbur Smith and Assoc. (July 1974) An Access Oriented Parking Strategy for the Boston Metropolitan Area.

** Kulash, D.J. (1971) Routing and Scheduling in Public Transportation Systems.

Off-street parking rate of $2.50 to $3.49, 1972

Source: Wilbur Smith & Associates,
An Access Oriented Parking
Strategy for the Boston
Metropolitan Area
July, 1974

FIGURE 4-3

BOSTON CBD - SELECTED PARKING CHARGES

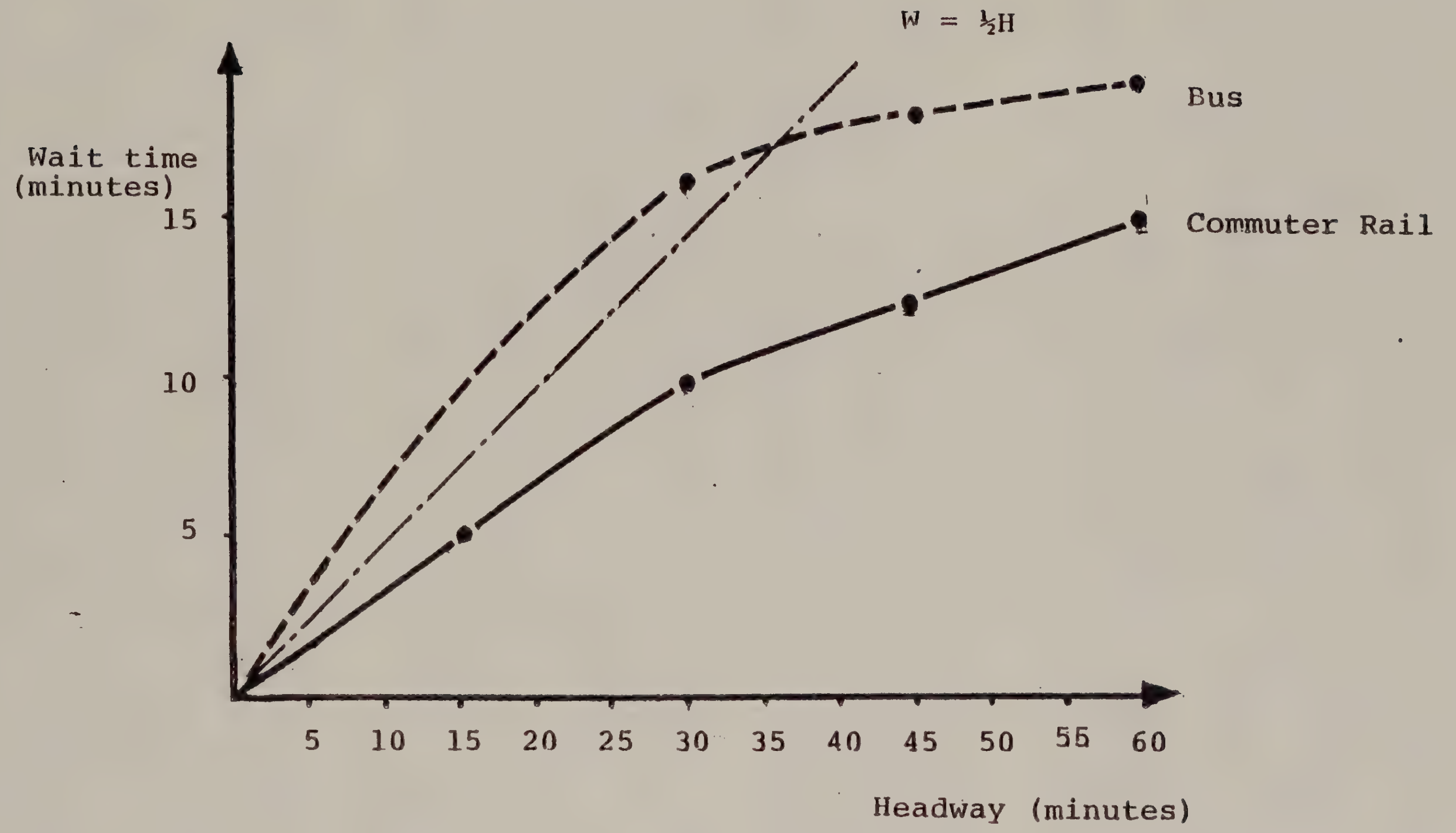


FIGURE 4-4

SELECTED WAIT TIME MODEL

3) 1976 Commuter Rail Survey
4) CTPS 1977 North Shore "Express Bus" Survey
5) Commuter Rail schedules and ridership counts
6) Updated highway speeds from the Dept. of Traffic and Operations at the MDPW.

Eventhough the raw data are in a form suitable only for use in conventional demand forecasting packages, it is possible to reconstruct the information into a form suitable for a disaggregate analysis and for estimation of disaggregate joint choice models. The details of the data processing, used in the CRIP study, is described in the following section. It should be emphasized, however, that there is the major shortcoming in the estimation process due to the aggregate orientation of the data. This shortcoming implies that it is impossible to recreate the complete contents of the choies made by each household.

4.2 DATA PROCESSING STEPS

The objective of the data processing is twofold. First, the household travel information must be processed into a form suitable for descriptive analysis. Second, a set of subsamples must be created in a manner that is general enough to allow for all the required model estimations.

The first major step is to organize the household information to allow complete access of travel pattern characteristics at any level of aggregation (link, chain, cycle, complete pattern). To achieve this, it is necessary to construct all of the levels above the link level from the link-oriented data. However, since some pieces of information might be missing or miscoded, the process of integration involves not only one of sorting the links, whenever possible, into complete chains, but also one of interpreting available information such that incompletely represented chains can be recognized.

A re-formating of the HIS file to permit recognition, without reanalysis of link-level information of the various behavioral levels was the key result of the chaining step. Figure 4-6 illustrates the typical structure of the file CHAINS, using as an example shopping trips. A hierarchy is created to describe chains for which more than one mode was used or more than one activity site category was visited. This hierarchy is to be used only for the purpose of first level identification of chain characteristics.

A parallel task in the organization of data for model estimation is the merging of level-of-service information into a single file which could be used for random access. The skim trees are in a form particularly unsuitable for

Codes in Order of Dominance

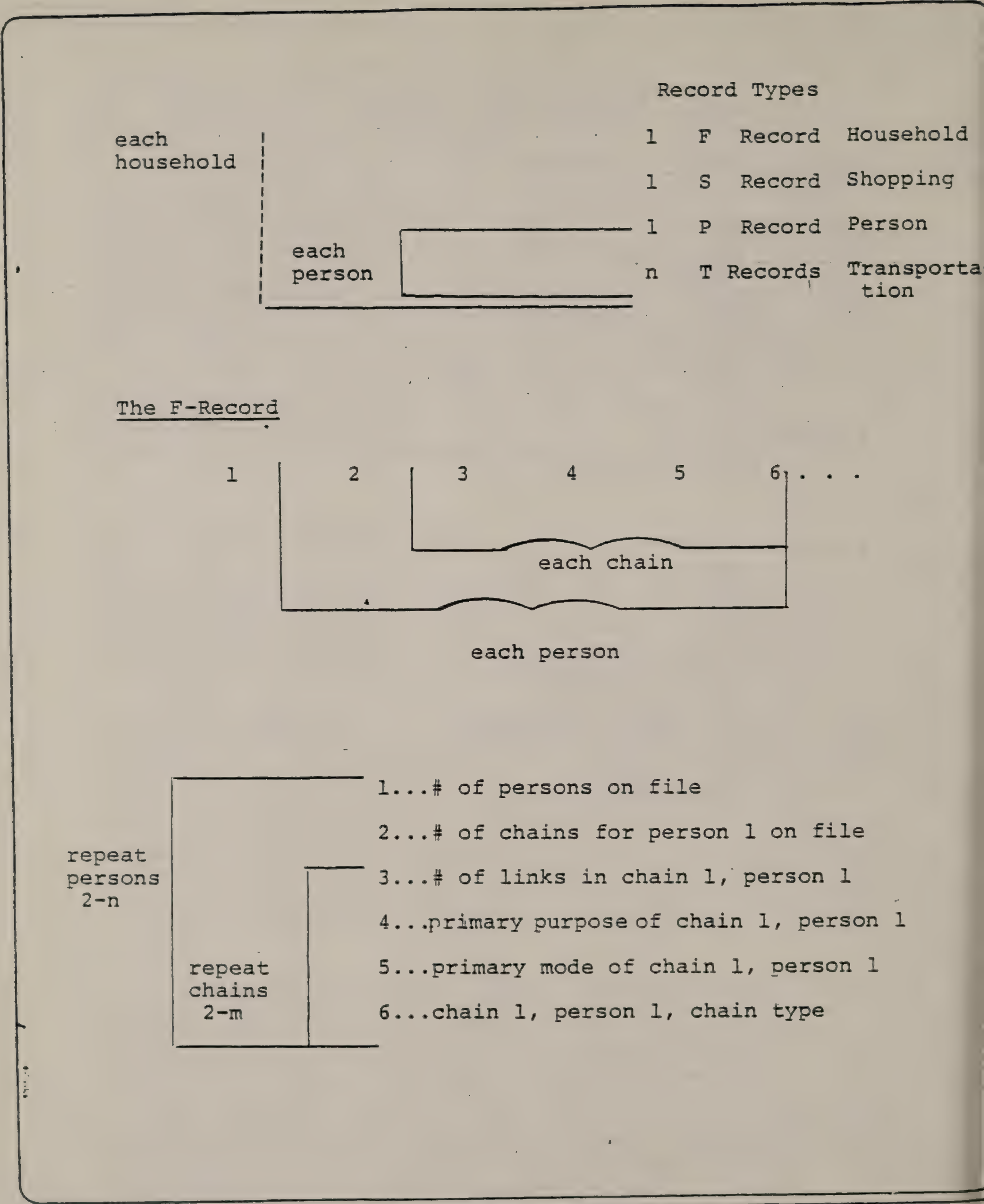
- Chain Types
  1. Fully completed
  2. Complete
     Except zones or purposes that do not match between links
  3. Home based
     Link missing on one end

- Primary Modes
  1. Auto driver or auto passenger
  2. All other modes

- Primary Purposes
  1. Home
  2. Work
  3. Shop
  4. School
  5. Social-recreational
  6. Personal business
  7. Medical, dental
  8. Work connected business
  9. Sightseeing
  10. Serve passenger
  11. Change modes

CODES IN ORDER OF DOMINANCE

FIGURE 4-5



STRUCTURE OF THE CHAINS FILE

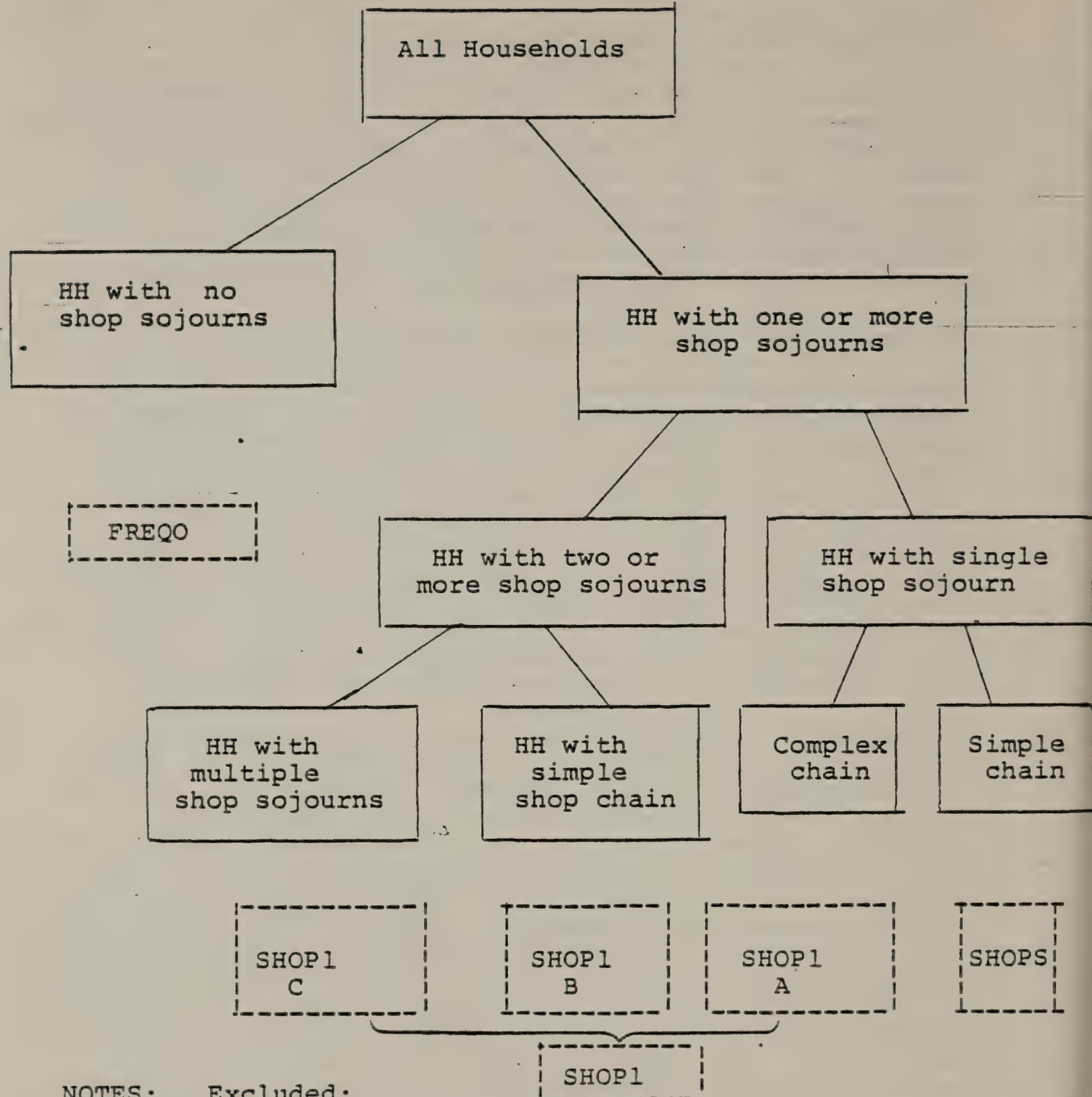
FIGURE 4-6

disaggregate modeling since they are arranged in separate sequential access tables by variable and in very different formats by mode (FHWA format for highway skim trees and UMTA format for bus and transit). This arrangement creates a problem for choice modeling where the level-of-service information for a complete set of alternatives (across modes for work trips as well as across destination for shopping trips) must be associated with each observation. Thus the data access must be random (by O-D pair) rather than sequential and the data required consist of the merged set of all the variables for all appropriate modes.

The zonal structure used for preparation of the skim trees is the CTPS zone system. Thus the description of origin-destination level-of-service for the metropolitan area requires data for close to 2 million pairs. Because of the relatively great number of one-way streets in the Boston CBD, triangularization of the matrix is ruled out, so that, with the values represented for peak and off-peak, as well as for auto and transit, the final file occupies close to 30 million bytes of disk storage. The O-D pairs are blocked into rows in order to reduce the costs of creation and access; a corresponding routine which supervises access (to reduce the number of requested input operations) and de-blocks the information makes the use of the file both convenient and inexpensive.

In the next processing step a set of sub-samples is created from the CHAINS file. This set is to be used for analysis and, later, for model estimations. As an example of the different types of data needed for modeling, three subsamples can be extracted from the data set to estimate a demand-for-shopping trips mode. The criteria used in extracting the subsamples are described in Figure 4-7. The three files, FREQO, SHOPL, and SHOPS, are created with additional information attached to each household's F records in order to allow further analysis of their composition. The intrazonal and cross-cordon flags indicate that the given chain includes at least one intrazonal link for the former, or a link which goes outside the metropolitan area for the latter. Intrazonal travel occurs with reasonably high frequency, and was specifically incorporated in the model formulation, while cross-cordon travel is usually incorporated infrequently, and thus was not considered.

For this example of modeling shopping trips, the final two processing steps involve the preparation of the FREQO and SHOPS files for logit estimation of the choice models. Before the final data sets associated with each model specification could be prepared, each household record had to include information on that household's full set of travel alternatives (for mode choice model over dimensions of car modes and transit mode, and for shopping model over dimensions of frequency, destination and mode choice). This is accomplished for a mode choice



NOTES: Excluded:
- HH with incomplete interviews
- HH iwth one or more incomplete chains

Additional F-Record Information:
- intrazonal, cross-cordon chain flag
- number of shop sojourns in chain
- chain duplication factor

CRITERIA FOR EXTRACTING SUBSAMPLES

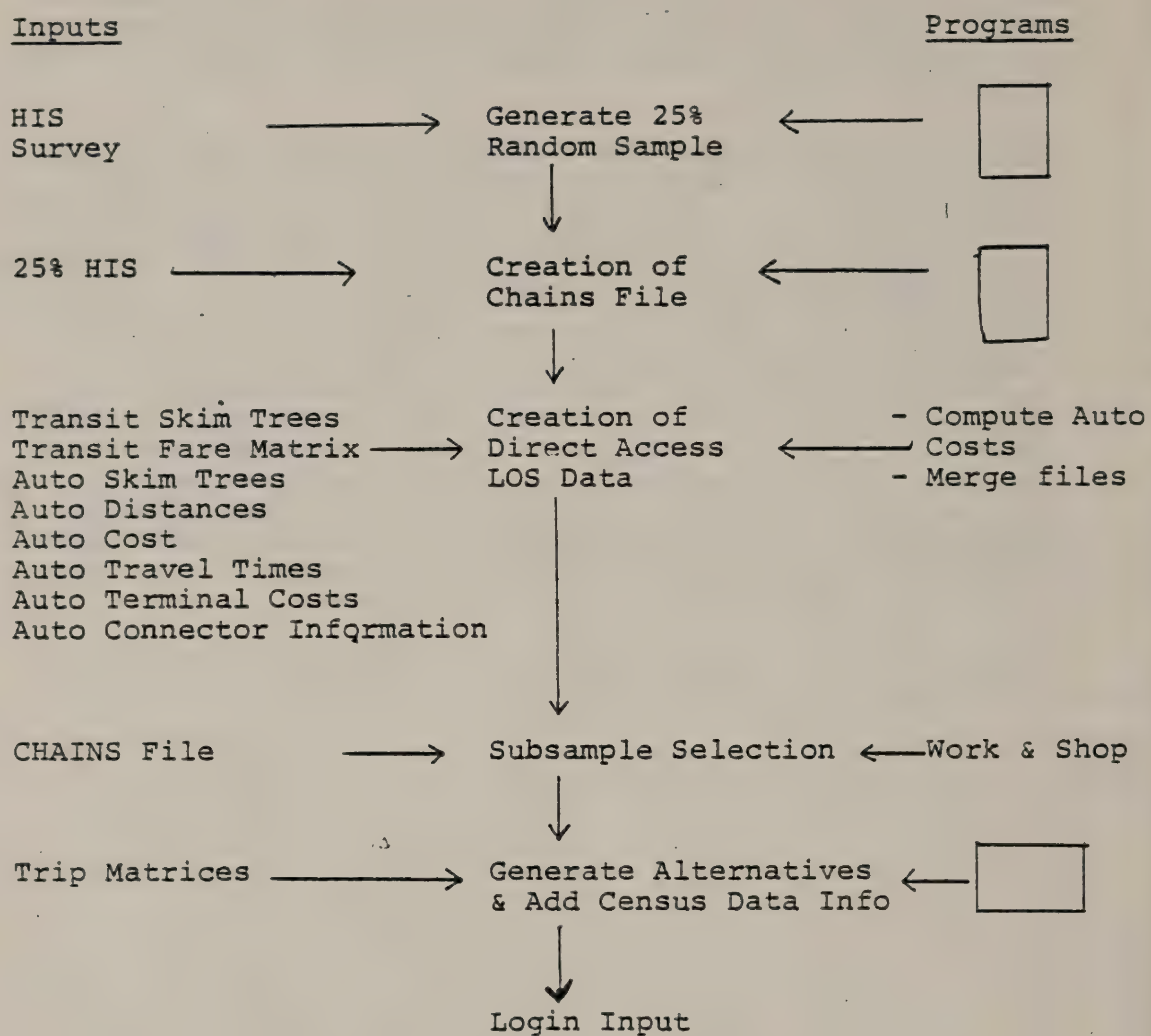
FIGURE 4-7

model by reference to the alternative modes available, for a shopping model by reference to a shopping O-D matrix from which the destination alternatives are constructed, and for model alternatives by looking at availability and allowing everyone the choice of making or not making a trip. Level-of-service data for these alternatives can be taken from the direct access file and appended to the household records.

Two potential problems associated with the estimation of a shopping model should be addressed here. The first arises from the size of the FREQO file. Because the file is significantly larger than the SHOPS file but in the same time period with less information than the SHOPS file, the FREQO file size should be randomly reduced. However, an appropriate compensation was made in the number of SHOPS households included in the estimation sample, in order to keep the proportion of households making shopping trips versus those not making shopping trips the same as that in the original sample. A second potential problem might arise from the peak period and partly in the off-peak. A weighted combination of peak and off-peak skim tree values can be assigned to the link, with the weights being determined by the proportion of the trip time occurring during the peak period*.

The details of processing can be explained by the flow chart depicted in Figure 4-8.

* BART data indicate that 10% of shopping trips are taken partly in peak period and partly in off-peak period.



DATA PREPARATION STEPS

FIGURE 4-8

5.0 THE WORK MODE CHOICE MODEL

5.1 INTRODUCTION

The general modelling methodology and the multinominal logit model used in this study were described in Chapter 3. The purpose of this chapter is to present the results of the models estimated for work trips.

In principle, two basically different groups of models could be estimated. One is a mode choice model for travellers who make a single home-work-home chain during the day. The second group of models include travellers who make a multiple trip chain during the day. In this study, primary emphasis was placed on the single chain model because it represents a less complex behavior pattern; it is also the more common situation in larger metropolitan areas such as Boston where distances to work tend to be greater.

5.2 THE MODEL

The work mode choice model explains the conditional probabilities of choosing a mode of travel for the work trip given residence and employment locations and given that a trip is made. Thus, the dependent variable can be denoted as follows:

$$P(m:M_{dt})$$

where m denotes an alternative mode and M_{dt} denotes the set of available modes to destination d for traveller t. The logit model predicting this probability is written as:

$$P(m:M_{dt}) = \frac{e^{U_{mt}}}{\sum_{m' \varepsilon M_{dt}} e} \qquad (5.1)$$

where U_{mt} is the utility of mode m to traveller t for the work trip to destination d (see (3.7)).
In general we write the utility of a given mode as

$$U_{mt} = X_{mt}'\theta \qquad (5.2)$$

$$= \sum_{K=1}^{K} X_{mtk}\theta_k$$

where a single coefficient vector was denoted as $\emptyset$ for all modes (see (3.9)). However, the utilities of the modes are different because the vector of variables x_{mt} assumes different values for different modes.

If a variable appears only in the utility function of mode m then it is a mode m specific variable which takes a value of zero in all other modal utilities. If a variable appears in the utility function of all modes then it is a generic variable. The value of a generic variable must not be equal to each alternative (i.e. each mode) for all observations or, mathematically, this variable is cancelled out (see section 3.4.2).

5.3 VARIABLES USED IN THE MODEL

The explanatory variables used in the work mode choice models are of two types; level of service characteristics, and socioeconomic variables. We have denoted the variables symbolically using abbreviations. For example, the variable "in-vehicle travel time" is written as "IVTT". If a variable is specified as mode specific then this is indicated by either prefixing or suffixing the following letters to the variable name.

train	T
bus	B
car	C

For example, if the variable IVTT appears in the car utility function with a coefficient different from that of other modes then it is denoted as CIVTT.

The variable name CON denotes a constant.

5.3.1 Level of Service Variables

The level of service variables used in the models were:

IVTT - In-vehicle travel time (in minutes)
For all modes it is the time spent in or on the vehicle

OVTT - out-of-vehicle travel time (in minutes)
For car it is denoted as POVTT which is defined as the time taken to walk to and from the parked vehicle as well as to park and unpark.
For bus and train OVTT consists of two

parts: WSOVTT and SOVTT. WSOVTT is defined as the time spent walking to and from the bus-stop or station. SOVTT is the time spent at a bus-stop or station as well as transferring from a bus to a train or vice versa.

OPTC - out-of-pocket travel cost (in cents) For car trips it was assigned a value equal to the fuel costs, in keeping with traditional expectations of perceived motoring costs; all parking charges were included (see section 4.5). For bus and train OPTC equals the costs of the fares.

5.3.2 Socio - Economic Variables

The socio-economic variables used in the models were:

HHINC - annual household income

PER - the number of persons in the household aged 5 years or older.

AOD - the number of private cars and non-commercial vans reported to be in the possession of the household, divided by the number of licensed drivers in the household, AOD was not permitted to have a value in excess of 1.0.

HHPOS - position in the household. This variable equals 1 for the head of the household, otherwise it equals zero. Since the purpose of this variable in the mode choice model was to represent car availability it was also assigned a value of 1 in the case of adults with a driving license who were not the head of the household if there was perfect car availability, i.e. if the variable AOD for that household was equal to 1.0.

OCC - the occupation of the traveller. A simple dummy variable was used taking the value of 1 for professionals, managers, and executives, and a value of zero for all other occupations.

A number of other variables available from the original data files, such as age and sex, were considered, as more detailed description of the variable OCC, but these were excluded during the course of the work on the basis of a priori considerations or simply due to the limited number of different specifications which could be estimated.

5.4 ALTERNATIVE SPECIFICATIONS

Various means of introducing the explanatory variables into the model were tried. Every model estimated was based on a different specification of the model utility functions. Several initial specifications were formulated based on a priori reasoning and past experience, including the results obtained from earlier models.

The initial estimation runs were deliberately restricted to rather simple specifications and small portions of the total sample (Fitchburg line only) since the level of service data for the full sample were not available until later in the study.

The results of these initial runs indicated that our coefficients were not substantially different from those in previous studies.

Earlier mode choice models tended to introduce the level of service characteristics as generic-variables. See for example PMM (1972), CRA (1972), and Ben-Akiva (1973). In this study this practice was not necessarily justified for the various components of out-of-vehicle travel time. In contrast to most other studies, home and work addresses could be precisely located, and thus the walking time to and from bus-stops or stations was known with a high degree of accuracy. Parking time however, could only be roughly estimated since no information was available on the location of parking places; similarly waiting and transfer times could only be roughly estimated. Thus, the different components of out-of-vehicle travel time were avoided in most of the specifications tried. The work by Stopher, Spear and Sucher (1974) on the measurement of inconvenience in urban travel suggests, however, that a division of out-of-vehicle travel time into its various components would be preferable to aggregation into a single variable. An explanatory run on the Fitchburg sample using in-vehicle travel time (IVTT) as a mode specific variable indicated that IVTT could be reasonably applied as a generic variable, since little difference was found between the mode specific coefficients (table 5-1). This means that a traveller values in-vehicle travel time the same regardless of mode. Other results show that logarithmic transformations of the travel time variables (IVTT or OVTT) had lower explanatory power than the untransformed forms.

	Coefficient	T Statistic
CAR	-.099	1.8
TRAIN	-.089	2.3
BUS	-.077	2.6

COEFFICIENTS OF IN-VEHICLE TRAVEL TIME ESTIMATED WITH SMALL SAMPLE

TABLE 5-1

The specification of the level of service variables which appeared to be the most suitable was:

IVTT	as a generic variable
POVTT	as a mode specific variable for car
WSOVTT	as a mode specific variable for bus and train
SOVTT	as a mode specific variable for bus and train

The major differences between the models reported in this chapter, and summarized in table 5-2, are in the specifications of the socioeconomic variables and the modal constants. The inclusion of socioeconomic variables in the utility function is clearly intended to explain differences in choice between different groups of persons. It can also facilitate the use of the model as a predictive tool for different market segments.

Modal constants have a totally different function compared to the other variables. If the variables included in the modal utility functions fully explain the mode choice behavior then the modal constants, or more generally the pure alternative effects, should equal zero. Thus with a perfect model specification and with perfect data it can be argued that no constants are necessary. Estimating a model without constants is in practice not recommended, however, since the estimated values of the coefficients of the variables included could be seriously affected if those variables do not fully explain the observed behavior.

The constants, or pure alternative effects represent therefore the effect of those variables which influence mode choice but were not explicitly included in the model. As was explained in section 3.5.2 the formation of the logit model is such that constants have to be alternative specific, or in this particular case, mode specific; a constant cannot be generic. If we have reason to believe that those variables which should have been included in the model to make it complete, but were in fact excluded, have different values for different situations, then the values of the constants will also differ. Under such circumstances the use of a model estimated on data for one area, to predict behavior in another area, or at a different period of time, or for a different socio-economic group, may well be questionable. In a mode

choice model the modal constants can be primarily attributed to level of service variables such as comfort, privacy, convenience, etc. which are either difficult or impossible to measure. An attempt was made in this study to account for the pure alternative effects through the introduction of various mode specific socio-economic and vehicle availability variables which could usually be expected to be highly correlated with a modal constant. The exclusion of constants was then considered acceptable if the coefficients of the various level of service variables were not significantly affected.

From the results of nine of the early models estimated it was observed that the variables HHPOS and OCC (position in household and occupation) had no significant influence on mode choice so far as the sample of data used for this study was concerned.

In general all the variables described above were introduced into the modal utility functions in a linear form. In a few cases an attempt was made to explore non-linear finite functions of the variables; i.e. the time variables and the car availability variable (AOD), with the latter utilized only as a car specific variable (CAOD). For the time variables a natural log transformation was tried. For the CAOD variable two finite functions were tried; the one was a product of CAOD and household income (HHINC) and the other was the product of CAOD and the natural log of in-vehicle travel time by car: CAODlnIVTT.

In a model with a maximum of 3 alternatives, only 2 (alternative specific) constants, or coefficients of a given socioeconomic variable can be identified (see section 3.4). The car mode was therefore used as the base alternative and the coefficients of mode specific variables, such as income, should be interpreted relative to the car model.

The estimation results for the alternative specifications tried with the full sample (411 trips) are given in Table 5-2. Models 3 and 4 are based on the final specification selected for the level of service variables, while models 1 and 2 show some of the other alternative specifications tried. The differences between models 3 and 4 are in the specifications of alternative specific constants as well as the socio-economic and vehicle availability variables. The estimation results and the differences between the models are discussed in detail in the following sections. The preferred model specification will be discussed in section 5.6.

5.5 COMMENTS ON ESTIMATED COEFFICIENTS

5.5.1 Values of Coefficients

The strongest a priori knowledge which we have about the estimated values of the coefficients is with regard to their signs. We expect that, with everything else held equal, a deterioration in the level of service offered by any mode will reduce the probability of that mode being chosen. Thus an essential requirement is that the coefficients of all level of service variables such as time or cost should be negative (of course the coefficient of a level of service variable such as comfort should be positive, if comfort was measured on a scale which increased with increasing comfort). This requirement is satisfied in all the models estimated for all the level of service variables.

There are also some a priori expectations with respect to the relationships between certain coefficients of level of service attributes. For example, one would expect the coefficient of an out-of-vehicle travel time variable to be greater than the coefficient of in-vehicle travel time. In all the specifications tried IVTT was, indeed, found to have a lower coefficient than any of the OVTT variables; the coefficient of walk to a bus-stop or station (WSOVTT) has approximately twice the value of the coefficient for in-vehicle travel time. Walking thus appears to be twice as inconvenient as riding in a vehicle. This relationship corresponds to the usual assumption used to create generalized costs in Wilson type models in the U.K. where the coefficient of excess time is usually taken to be twice that of in-vehicle travel time (McIntosh and Quarmby, 1970). Waiting time at a bus-stop or station appears to be more inconvenient than in-vehicle travel time. This is in concert with the usual assumption mentioned above, as well as with other U.S. studies in which the coefficient of waiting time is usually taken to be 2.5 times that of in-vehicle time (e.g., Pratt and Deen, 1967).

Everything being equal, one would expect that as car ownership increases the probability of choosing car as the mode of transport would increase and, thus, that the probability of choosing other modes would decrease. One would therefore expect that the coefficient of car availability (CAOD) would be positive.

Household income and modal constants appear in the utility function of more than one mode and therefore interpretation must relate to their relative values and not their absolute values. In the model B example the relative values of the coefficients of household income indicate that as household income increases, and everything else is held constant, the increase in the probability of using the car is greater than that for other modes. While

the probability of choosing a bus will decrease relative to all other modes. Between these two extremes is the choice of train, which decreases relative to car and increases relative to bus. This could reflect the socio-economic status of a bus as a transit mode.

The modal constants and socio-economic variables could be interpreted as representing the pure preferences for the alternative modes if the utility derived from the level of service characteristics was equal across all modes. A direct interpretation of this kind is easier when all the level of service characteristics are introduced as generic variables. For example these variables in model 1 imply that if IVTT and OVTT are equal across modes then an individual with perfect car availability, i.e. with AOD equal to 1, will rank the modes in the following order:

car, train, and, lastly, bus. This ranking is also implied by model 4.

5.5.2 Stability and Reliability of the Estimated Coefficients

The reliability and stability of the estimated coefficients can be observed in several ways including the relative magnitudes of the standard errors and the variability of the estimates both across different specifications and across different subsamples.

The magnitude of the standard errors of the estimated coefficients (compared with the magnitude of the estimated coefficients) is relatively small for the travel time variables; for bus the standard error is relatively higher for some modal constants and socio-economic variables, in particular the moped specific variables. This could also be observed from the variability of the estimated coefficients of the same variables across different specifications.

From Table 5-2 it is evident that the coefficients of travel time in different model specifications are quite stable, in particular the coefficient of IVTT. On the other hand, some of the coefficients of the socio-economic variables and the constants appear to be less stable. This pattern was also observed in the comparison of different subsamples.

5.6 PREFERRED MODEL SPECIFICATION

Of all the model specifications tried, that for model 4 appears to be the most satisfactory. This conclusion as well as aspects of some of the other models estimated is discussed in this section.

As discussed in section 5.4, the formulation of the level of service variables in models 3 and 4 seems to be

VARIABLE	MODEL 1	MODEL 2	MODEL 3	MODEL 4
IVTT	-.0675 .0081		-.0635 .0106	-.0598 .0079
ln IVTT		-1.475 .235		
OVTT	-.1201 .0163	-.1595 .0198		
WSOVTT			-.1201 .0194	-.1091 .0238
SOVTT			-.0791 .0154	-.0704 .0195
OPTC/HHINC	.0066 .0095	.0195 .0096	.0395 .0154	.0191 .0099
CAOD	.5778 .4211			
CAOD*HHINC		.4895 .0986	.2979 .1386	
CAOD*lnIVTT				.9919 .211
TCON	1.9115 .6174	3.1583 .8771		1.501 .904
THHINC			.1102 .1534	
χ^2 (d.f.)	311 (5)	351 (5)	326 (6)	330 (6)
ρ^2	.36	.33	.39	.41
$\bar{\rho}^2$	.36	.32	.38	.40

NOTE: Variable Key on following page.
No. of Observations: 411

ESTIMATION RESULTS OF WORK MODE CHOICE MODEL

TABLE 5-2

Variable Key

IVTT	In-vehicle travel time
InIVTT	Natural log of in-vehicle travel time
OVTT	Out-of-vehicle travel time
WSOVTT	Time spent walking to and from bus stop or rail station
SOVTT	Time spent at a bus stop or rail station
OPTC/HHINC	Out-of-pocket travel cost/annual household income
CAOD	Auto ownership specific to car mode
CAOD*HHINC	Auto ownership specific to car mode * annual household income
TCON	Train constant
THHINC	Annual household income specific to train mode

ESTIMATION RESULTS OF WORK MODE CHOICE MODEL

TABLE 5-2 CONT'D.

superior to that utilized in models 1 and 2. The coefficients of all the level of service variables in model 3 and 4 have the expected signs as well as the expected relative values. Therefore any preference between specifications 3 and 4 must be based on the behavior of the socio-economic variables and the modal constants.

Model 4 is superior to model 3 when compared in terms of goodness of fit and the significance of the coefficients.

In conclusion, Model 4 appears to have the most satisfactory specification of those models estimated and presented in table 5-2. In the subsequent section of this chapter this model is tested for its forecasting abilities.

5.7 PREDICTION TESTS

Two types of prediction tests were applied; the first of these was a disaggregate test designed primarily to determine how well the model fits the observed data. The second test was with aggregate data and was designed to test the applicability of the model for aggregate predictions.

5.7.1 Disaggregate Predictions

In disaggregate predictions the explanatory variables are used to predict individual mode choice probabilities. These individual probabilities are summed across a group of travellers and compared with the observed modal shares for the same set of individuals. When the group of travellers consists of the complete set of individuals used in the estimation of the model, this test can be viewed as a test of goodness of fit. However, the estimation procedure utilized in this study guarantees that if a model specification includes a constant the results of such a test will be perfect for the alternative to which that constant relates.

For model 4 this implies that a disaggregate prediction test with the complete data set used in model estimation will reproduce perfectly the total public transport share since a public transport constant was included. The results of this test indicate that the mode split between car, train and bus was indeed perfectly reproduced.

5.7.2 Aggregate Predictions

Disaggregate prediction gives some indication as to how well the model fits the actual observed disaggregate data. However, in normal predictive work disaggregate data are not usually available and thus the model must be applied as an aggregate model for predictions. As

explained in Koppleman, 1974, simple substitution of group averages for the explanatory variables will result in a biased forecast of the average probability, or share; this bias will only disappear if all individuals in the group for which predictions are being prepared are identical in terms of the values of all the explanatory variables.

Between the two extremes of disaggregate predictions and the use of averages for the entire group in aggregate predictions, it is possible to identify a stratification scheme, or system of market segmentation, such that the aggregation bias can be assumed to be small and, within the context of the application, to be negligible. Stratification in this study is based on income groups (low, median, and high).

The results of the prediction tests were considered acceptable in view of the fact that for each individual group there is also probably an error in the observed share, relative to the total population, due to sampling. Since this error increases with decreasing sample size, the greater the number of the observed travellers utilized to compute the observed aggregate share the more meaningful the aggregate prediction tests. Thus an adequate evaluation of the aggregate prediction errors can only be undertaken for those zonal-pairs with a high trip density, i.e., those where the error in the observed share could be assumed to be negligible.

The aggregate mode choice predictions, based on a stratification of travellers into those with a car available and those with no car available, was satisfactory. This implies that the model can be usefully applied to aggregate predictions in transportation planning studies.

6.0 THE SHOPPING-TRIP MODEL

6.1 INTRODUCTION

The shopping-trip model developed during the course of this study is a joint destination and mode choice model. Thus, given the number of shopping trips originating from a residential area, the model can be used to distribute the trips over the alternative shopping destinations and also over the relevant alternative modes of transport.

It would seem desirable that a truly behavioral shopping model should have a simultaneous structure in which the choices of frequency, time of day, destination and mode are all considered. However, in view of the overall objectives and scale of this study, the scope of the shopping model developed had to be limited.

Traditionally, urban travel demand forecasting models treat the choices of frequency and time of day independently of the transport level of service and, thus, independently of either destination or mode choice. The data available from conventional urban transportation surveys are thus not generally suitable to the development of frequency choice models, nor are they suitable to the satisfactory development of models in which the choice of the time of day at which a trip is made is explicitly modeled.

Given the resources available and the form of the models currently used in urban transportation planning studies, it was considered that a simultaneous destination and mode choice model provided the best scope for the introduction of immediate improvements to existing techniques. Furthermore, the implementation of a simultaneous model of destination and mode choice in software packages generally in use in urban transportation planning is likely to require fewer modifications than a more complex model in which frequency and time of day are also included.

Most of the work to date on the behavioral value of time in travel-demand modeling has been concerned with home-based work trips and, more specifically, with mode choice for such trips. Travel-demand forecasting for other purposes has therefore tended to be based upon the same values of time, or relative generalized price coefficients (see, e.g., McIntosh and Quarmby, 1970).

The models described in this chapter together with the models described in chapter 5.0 provide some very useful information on the validity of this approach.

6.2 THE MODEL

The model described in this chapter is one which predicts the joint probability of choosing a destination and mode combination given that a trip is made. Thus the dependent variable can be denoted as follows:

$$P(d,m:DM_t) \quad \text{or} \quad P_t(d,m)$$

where m denotes an alternative mode, d denotes an alternative destination and DM_t denotes the set of relevant destination and mode combinations available for a shopping trip to traveler t.

The logit model predicting this joint probability is written as follows:

$$P(d,m:DM_t) = \frac{e^{U_{dmt}}}{\sum_{d',m' \varepsilon DM_t} e^{U_{d'm't}}} \tag{6.1}$$

where U_{dmt} is the utility to traveler t from going to destination d by mode m (see section 3.5.1).

The utility functions are assumed to be linear in the coefficients as follows:

$$\begin{aligned} U_{dmt} &= X_{dmt}'\theta \\ &= \sum_{k=1}^{K} X_{dmtk} \cdot \theta_k \end{aligned} \tag{6.2}$$

where X_{dmt} is a vector of finite functions of the explanatory variables and θ is a vector of coefficients.

The alternative modes used in this study are: car, bus and train. The alternative destinations are the Boston CBD and the closest regional shopping center.

6.3 VARIABLES USED IN THE MODEL

The explanatory variables used in the shopping models include all those used for the work models and described in section 5.3. In addition, retail employment was used to describe the individual shopping centers; this was denoted as EMP. This variable can be considered as a proxy for the shopping opportunities available at the shopping centers. Other attraction variables which were available, such as employment in those services which could make a shopping location more attractive (banking, hair-dressing, etc.), were not used in any of the models estimated.

6.4 ALTERNATIVE SPECIFICATIONS

The alternative specifications formulated for the shopping model were based to a great extent on the same sort of reasoning as was applied to the development of the work mode choice model described in chapter 5.0. The work on the development of the shopping model was commenced after the completion of the work mode choice models and was thus able to benefit from the results of that work.

The level-of-service variables were specified in the same manner as models 3 and 4 of the work mode choice model; i.e., IVTT, WOVTT, POVTT, WSOVTT, and SOVTT. The alternative specifications tried thus differ only in the manner in which the vehicle availability and attraction variables were introduced.

Due to the distinct difference between the center of Boston and all the other, local shopping centers--i.e., those in Burlington, Braintree and Newton--a number of variables were introduced in some specifications twice; once specific to the Boston centers and once specific to all the other, local centers. Variables specific to the Boston centers are denoted by the prefix or suffix "B", while those specific to the local centers are denoted by the prefix or suffix LOC.

In order to minimize potentially abortive work, any variable which had not been found to be satisfactory in thw work mode choice models was excluded from the specifications tried for the shopping model, with the exception of out-of-pocket travel costs.

6.5 DISCUSSION OF ESTIMATION RESULTS

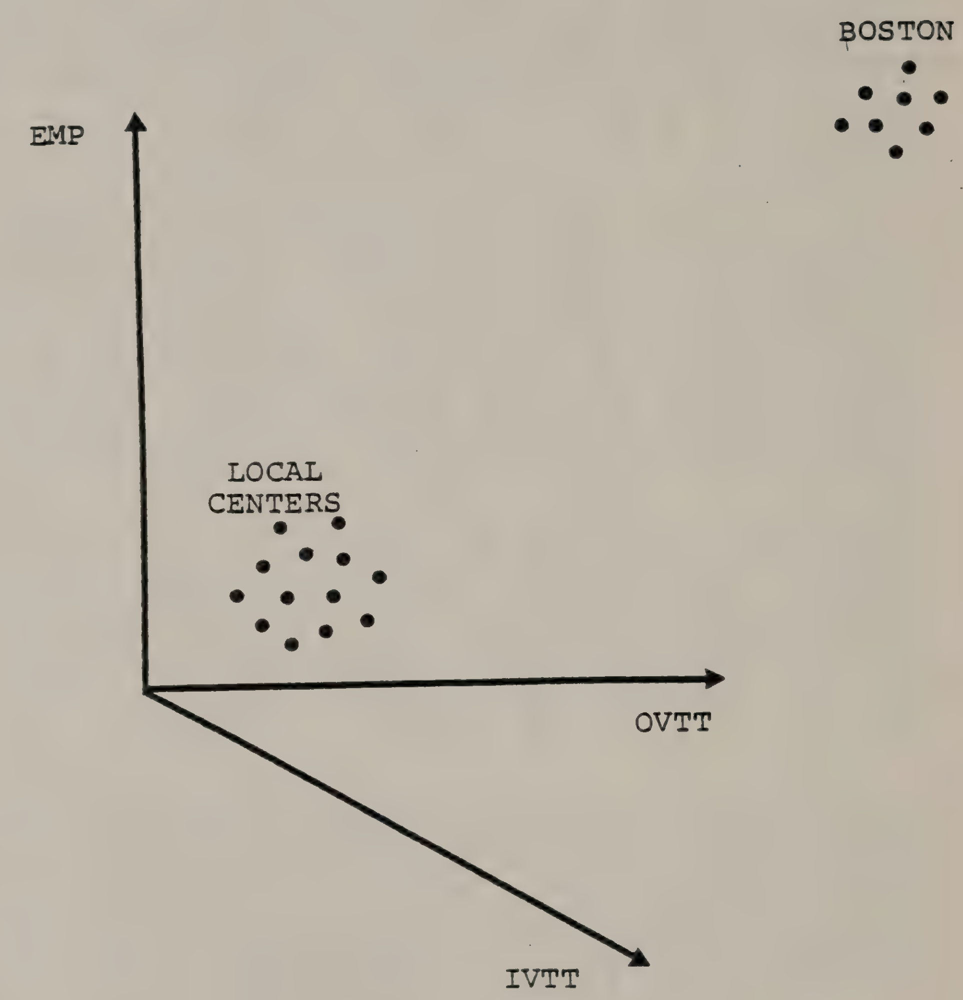
A full discussion of the results of the models estimated must take place within the context of the data set utilized. It is therefore necessary to consider

the characteristics of the alternative shopping destinations, since those for Boston are substantially different from those of all the other local shopping centers.

The data set can be described in the context of a multidimensional space in which the axes are defined by the explanatory variables. For a given observation (i.e., a person making a shopping trip), an alternative destination and mode combination is described by a point in this space. An observation with a total of DM alternatives will be represented by DM points. For any observation in the data set utilized for this study, this procedure will result in two clusters of points, and these two clusters are widely separated. One large cluster contains all the alternatives relating to the local shopping centers and the second, and smaller, cluster contains the alternative modes for Boston. The peculiarity of the data set is that the Boston cluster will be very much further away from the origin than the local cluster. This situation can be depicted in a simplified way as shown in Figure 6-1. The distance between the two clusters is evidently very large if we consider, for example, retail employment and the average distance of the center of Boston from the residential areas. Not only is the center of Boston nearly 20 times as large as the largest of the local shopping centers, but the average distance from the residential area to a shopping center is about ten times as great for the center of Boston as it is for the other, local centers. Furthermore, Boston is the only center to which trips were made by public transport.

This structure of the data set suggests a hypothesis of a hierarchy of decisions: first, a choice between shopping in the center of Boston and shopping locally, and then, secondly, if shopping locally was chosen, a choice among the local centers. The flaw in this hypothesis is that its reasonableness stems only from the fact that no medium-sized shopping centers existed in the sample. Indeed, a closer examination of the cluster of local centers will reveal a hierarchy of centers within this cluster. Thus, any explicit modeling of a specific hierarchy will be arbitrary, while a model which considers all alternatives simultaneously will be more general.

Although this latter approach is sound in theory, the existing data set creates a specific problem in that the weight of the center of Boston can have a major influence on the determination of the model coefficients. In general, while it is desirable to have maximum variability in all of the variables considered,



SHOPPING DATA SET

FIGURE
6-1

in this particular case a large portion of the variability is of a discontinuous nature, due to the fundamental differences between the local and Boston alternatives. Unfortunately, it is impossible to determine the effect of this discontinuity on the estimation results without applying the model to a data set which exhibits more continuous characteristics. Although the problem of the relative sizes of the alternative shopping destinations cannot be resolved within the whole study area, other problems of discontinuity could be resolved by taking a sample for a corridor or sector through the study area.

One consequence of the characteristics of the data set available is a lack of variability in the public transport services. While the walk-to-the-station variable (WSOVTT) has sufficient variability, the station-waiting-time variable (SOVTT) has extremely limited variability, because bus and train were used only for trips to Boston; this is probably the reason why the coefficient of SOVTT in model 1 is not significant (see Table 6-1).

Model 1 has a specification identical to that of the final work mode choice model, model 4, with the addition of the retail employment variable (EMP). As noted above, the coefficient of SOVTT was found to be insignificant, as was that of PTCON. A second model, model 2, was therefore estimated, in which these two variables (SOVTT and PTCON) were omitted. From the results given in Table 6-1 it can be seen that this omission has negligible effects on the coeffficents of the remaining variables; indeed, the standard error of WSOVTT was reduced by 50 percent. The two variables SOVTT and PTCON typify the particular problems of the data set utilized.

Due to the lack of variability in SOVTT and the fact that it is an alternative specific variable applied only to those alternatives to which PTCON is also applicable suggests that a high degree of collinearity could be expected. Furthermore, insofar as the observed choices are concerned, both of these two variables occur only when Boston was the chosen alternative.

In view of the discontinuity problems described above, the retail employment variable (EMP) was split into two variables in model 3. One was specific to the local centers (EMPLOC) and the other to the center of Boston (EMPEI); the Boston specific variable was thus essentially a constant, but taking the value of the retail employment in Boston. This change gave a significant improvement in the goodness of fit in comparison with models 1 and 2, with $\bar{\rho}^2$ increasing from 0.25 in model 2

VARIABLE	MODEL 1	MODEL 2	MODEL 3	MODEL 4
IVTT	-.1740 .0116	-.1766 .0129	-.1531 .0125	-.1566 .1179
WOVTT	-.1988 .0160	-.1945 .0152	-.2122 .0177	-.1951 .0157
POVTT	-.4438 .0486	-.4268 .0465	-.4325 .0511	-.3833 .0484
WSOVTT	-.2282 .0464	-.2557 .0232	-.2605 .0246	-.2350 .0275
SOVTT	-.0148 .0689			
OPTC				.0057 .0136
CAOD*lnIVTT	.4885 .1985	.4816 .1989	.5734 .2197	.4035 .2129
TCON	.5789 1.9296			
EMP	.0024 .0001	.0024 .0001		
EMPB			.0027 .0002	
EMPLOC			.0344 .0017	
lnEMP				.7419 .0609
B CON				3.2645 .8060
χ^2 (d.f.)	695.7(10)	694.5(8)	1290.6(9)	794.4(10)
ρ^2	.25	.25	.46	.28
$\bar{\rho}^2$	.25	.25	.46	.28

No. of Observations: 411

NOTE: Variable Key on following page.

ESTIMATION RESULTS OF SHOPPING-TRIP MODE AND DESTINATION CHOICE MODELS

TABLE 6-1

Variable Key

IVTT	In-vehicle travel time
WOVTT	Time spent walking to a destination
POVTT	Out-of-vehicle travel time for car mode
WSOVTT	Time spent walking to and from bus stop or rail station
SOVTT	Time spent at a bus stop or rail station
OPTC	Out-of-pocket travel cost
CAOD*InIVTT	Auto ownership specific to car mode * natural log of in-vehicle travel time
TCON	Train constant
EMP	Retail employment
EMPB	Retail employment in Boston
EMPLOC	Retain employment in local centers
InEMP	Natural log of retail employment
BCON	Boston constant

ESTIMATION RESULTS OF SHOPPING-TRIP MODE AND DESTINATION CHOICE MODELS

TABLE 6-1 CONT'D.

to 0.46 in model 3. This change indicates that the difference between the local centers and Boston was not captured by a linear EMP variable.

The effects of the replacement of a single employment variable by two illustrate some of the particular problems which can be associated with a data set displaying characteristics such as the one used in this study.

The local employment variable, EMPLOC, has a much larger coefficient (0.0344) than the Boston employment variable, EMPB (0.0027), although the coefficient of the joint employment variable (EMP) in model 2 is 0.0024. The fact that the coefficient of the joint variable EMP is almost equal to that of the Boston employment variable EMPB indicates the weight of the Boston alternatives in the determination of the coefficient of the joint variable. The difference between the coefficients of EMPLOC and EMPB could be interpreted as representing an effect of diminishing marginal returns of shopping center size.

The attractiveness of a center should thus be so specified in the utility function that it increases less than linearly with increasing employment. This means that if a single employment variable is used in the utility function it should be a concave transformation, such as lnEMP, as used in model 4. The statement about diminishing returns of size applies only to the utility functions. Therefore, the diminishing effect of size on the utility does not necessarily imply a diminishing effect in terms of actual trips per employee. This latter effect is also a function of the actual choice probability and can be determined only by using the actual values of the variables.

If a variable is introduced in the additive utility function in its natural log transformation, then the elasticities with respect to this variable are not a function of the value of the variable itself, but of its coefficient and the choice probabilities (see section 3.5.4). Therefore the coefficient of 0.74 of lnEMP in model 4 implies that the choice probability is always inelastic with respect to employment, since a one-percent increase in size results in less than a one-percent increase in the probability of that alternative being selected. Thus, the larger the center and, hence, the greater the probability of choice, the more inelastic its attractiveness with respect to size.

In model 3 the inclusion of variables specific to the center of Boston made it inadvisable to include a public transport constant; furthermore, this was found to be insignificant in model 1.

In model 4 the car availability variable CAOD was included in the same form in which it had been included in models 1, 2 and 3, i.e., CAODlnIVTT, and the EMP variable was introduced in its natural log transformation, lnEMP. Although out-of-pocket travel cost, OPTC, had been found to be insignificant in the work mode choice models, it was decided to introduce it in model 4; a similar result was, however, obtained.

A Boston constant, BCON, was introduced to account for any pure alternative effect, i.e., any model specification deficiencies. This constant was found to be highly significant, thus suggesting that lnEMP does not explain all the differences in attractiveness between the center of Boston and the local centers.

The positive coefficient of BCON indicates that Boston center has an added attractiveness not captured by the retail employment variable.

While model 4 would seem on a priori reasoning to have the best specification of those tried, the goodness of fit is very much lower than in the model 3. The coefficients of all the level-of-service and vehicle-availability variables are, however, the same. The only differences between the two models is the manner in which the employment variable was introduced, and the inclusion in model 4 of a Boston constant (due to perfect collinearily with EMPEI, such a constant could not have been included in model 3) and out-of-pocket travel cost.

6.6 COMPARISON OF THE WORK MODE CHOICE MODEL WITH THE SHOPPING MODEL

The shopping model described in this chapter is a simultaneous model of mode and destination choice, while the work model described in chapter 5.0 is a conditional model of mode choice given the destination. In order to provide a more direct comparison between the two models, a conditional mode choice model given the destination was also estimated for the shopping sample. This model was estimated with a specification identical to that of model 4 for the work-choice model: the comparison suggests that the coefficients of IVTT are identical for both models, while all the coefficients of the out-of-vehicle travel time variables are greater for shopping than for work. This would appear to be reasonable since it could be expected that out-of-vehicle travel time relative to in-vehicle travel time will be regarded as more inconvenient in the case of shopping trips than in that of work trips, not only due to the need to carry the purchases, but also in

relation to the total duration of the home-to-home journey. The greatest increases in the weights of the out-of-vehicle travel time elements are in the coefficients of the two public transport specific variables, WSOVTT and SOVTT. This comparison can have important implications in travel demand modeling since it indicates that there could be no justification for the use of a unique set of generalized price coefficients across all trip purposes.

A further important comparison which should be made is between the conditional mode choice shopping model and the joint destination and mode choice shopping models (model 3). This is especially relevant for the level-of-service variables.

The significant differences between the two models are in the coefficients of IVTT and OVTT. The increase in the absolute values of the coefficients in the joint model relative to the conditional model could be attributed to the effect of distance on shopping destination choice.

This effect could be a result of a tendency to visit nearby shopping centers which are more familiar. Thus, these differences could be a result of not including a familiarity variable in the joint model (distance could have been a proxy). However, no model is perfectly specified, and it is also possible to assume that the coefficient of IVTT in the conditional model is biased due to mis-specification of modal captivity. It is not clear which choice is mis-specified more severely, destination choice or mode choice. It is clear, however, that, given the differences between the joint and the conditional model, and given the a priori assumption of a simultaneous structure, the results of the joint model are more reliable and should in general be used.

REFERENCES

Adler, Thomas J., A Joint Disaggregate Model of Non-Work Urban Passenger Travel Demand, S.M. Thesis, Department of Civil Engineering, M.I.T., Cambridge, Massachusetts, 1975.

Aldana, Eduardo, Towards Microanalytic Models of Urban Transportation Demand, Ph.D. Dissertation, Department of Civil Engineering, M.I.T., Cambridge, Massachusetts, 1971.

Atherton, Terry J., Approaches for Transferring Disaggregate Travel Demand Models, S.M. Thesis, Department of Civil Engineering, M.I.T., Cambridge, Massachusetts, 1975.

Ben-Akiva, Moshe, Structure of Passenger Travel Demand Models, Ph.D. Dissertation, Department of Civil Engineering, M.I.T., Cambridge, Massachusetts, 1973.

Ben-Akiva, Moshe, and Lerman, Steven R., "Some Estimation Results of a Simultaneous Model of Auto Ownership and Mode Choice to Work", Transportation, Vol, 3, No. 4, 1974.

Charles River Associates, Inc., A Disaggregated Behavioral Model of Urban Travel Demand, Federal Highway Administration U.S. Department of Transportation, 1972, 1968.

Cambridge Systematics, Inc., A Policy Sensitive Modal Split Model for the Los Angeles Region, Draft Final Report, Southern California Association of Governments, 1975.

deDonnea, F.X., The Determinants of Transport Mode Choice in Dutch Cities, Rotterdam: Rotterdam University Press, 1971.

Fleet, C.R. and S.R. Robertson, "Trip Generation in the Transportation Planning Process", Highway Research Record No. 240, Highway Research Board, Washington, D.C., 1968.

Koppleman, Frank, "Prediction with Disaggregate Models: The Aggregation Issue", Transportation Research Record No. 527, Transportation Research Board, Washington, D.C., 1974.

Kraft, G., and M. Wohl, "New Directions for Passenger Demand Analysis and Forecasting", Transportation Research, Volume 1, No. 3, November, 1967.

Kulash, D.J., Routing and Scheduling in Public Transportation Systems, 1971.

Lave, C.H., "A Behavioral Approach to Modal Split Forecasting", Transportation Research, Vol. 3, No. 4, December, 1969.

Lerman, Steven, A Disaggregate Behavioral Model of Urban Mobility Decisions, Ph.D. Dissertation, Department of Civil Engineering, M.I.T., Cambridge, Massachusetts, 1975.

Lisco, Thomas E., The Value of Commuters' Travel Time: A Study in Urban Transportation, Ph.D. Dissertation, Department of Economics, University of Chicago, 1967.

Luce, R.D. and P. Suppes, Preference, Utility and Subjective Probability in: R. Luce, R. Bush and E. Galanter, eds., Handbook of Mathematical Psychology, III, (Wiley, N.Y.) 1965.

McCarthy, G.D., "Multiple Reprogram Analysis of Household Trip Generation - A Critique", Transportation Research Record No. 297, Transportation Research Board, Washington, D.C., 1969.

McFadden, D., and F. Reid, Aggregate Travel Demand Forecasting from Disaggregated Behavioral Models Working Paper No. 228, (University of California, Berkeley), 1974.

McIntosh, P.T., and D.A. Quarmby, "Generalized Costs and the Estimation of Movement Costs and Benefits in Transportation Planning", MAU Note 179, London: Department of Environment, 1967.

Oi, W.Y., and P.W. Shuldiner, An Analysis of Urban Travel Demands, (Northwestern University Press, Evanston, Ill.), 1962.

Peat, Marwick, Mitchell & Co., "Implementation of the N. dimensional Logit Model", San Diego County, Co. Comprehensive Planning Organization, 1972.

Pratt, R.H., and T.B. Deen, Estimation of Sub-Modal Split Within the Transit Mode, Santa Barbara, California, NTAC, 1967.

Strotz, "The Empirical Implications of a Utility Tree", Econometrical, 25:269-80, 1957.

Tversky, A., "A Choice by Elimination", Journal of Mathematical Psychology, 1972a.

Tversky, A., "Elimination by Aspects: A Theory of Choice", Psychological Review, 1972b.

Wilbur Smith and Associates, An Access Oriented Parking Strategy for the Boston Metropolitan Area, July, 1974.

TECHNICAL APPENDIX A.3

TITLE Description of Commuter Bus Alternative

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ABSTRACT

As part of the analysis of the commuter rail system, this appendix provides a detailed description of the Commuter Bus Alternative. Included in this appendix are: a description of existing transit services, detailed delineation of each commuter bus route, analysis of potential operators of each route and the impact of analyzed bus services on traffic and circulation.

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COMMUTER BUS ALTERNATIVE

1.0 INTRODUCTION

1.1 SCOPE OF APPENDIX

As part of the analysis of the commuter rail system, this appendix provides a detailed description of the Commuter Bus Alternative -- the fourth alternative analyzed in the CRIP Plan Refinement Study.

This appendix includes: a description of existing transit services and detailed delineation of each commuter bus route. In addition, this appendix analyzes potential operators of each route (MBTA or private carrier); fixed facilities requirements, including garage/layover facilities and downtown terminals; and the impact of analyzed bus services on traffic and circulation.

1.2 SUMMARY OF PROCEDURE USED TO DESIGN ROUTES

As part of the analysis of the commuter rail system, an alternative commuter bus service was designed for each corridor serviced by the various commuter rail lines. The first step in designing this service was to examine travel patterns on the line. A review of ticket audits and the 1976 on-board survey revealed that a negligible amount of travel occurs between station pairs outside Boston with the exception of the Eastern and Fitchburg routes. Therefore on-line trips were ignored except for the two lines noted and in the majority of corridors, a network was designed to serve the needs of the Boston trips only.

On the Eastern Route about 12% of all trips are made between stations outside Boston. However the trip pattern is so unstable that it was deemed impossible to design a commuter bus service to serve these trips. Therefore a network was designed to serve the needs of Boston trips only.

About 25% of all trips on the Fitchburg Route are made between stations outside of Boston. More than half of this travel is accounted for by trips to or from the Cambridge Station. Because of this volume, bus service was designed from suburban stations to Cambridge as well as to Boston.

In choosing downtown terminal locations, the destinations of users were considered. Although northside rail lines terminate at North Station, the majority of users have destinations closer to downtown Boston. Therefore bus routes designed to replace Northside rail service were terminated at Haymarket Square which is a more convenient location for most riders. However, the existing Haymarket bus terminal is congested during peak hours, and therefore additional facilities would be needed for the commuter bus service.

All Southside commuter rail routes include a stop at Back Bay before terminating at South Station. During the relocation of the Orange Line, trains on the Shore Line, Stoughton and Franklin routes will temporarily by-pass Back Bay with shuttle service to be provided to Back Bay. Bus routes to replace Southside rail service were designed to serve South Station and Copley Square. Because of the traffic congestion between these points separate routes to the two stations would be provided if the volume of riders warranted it.

Existing rail schedules and volumes were used as a basis for developing the commuter bus schedules. In general, bus schedules were designed to maintain current Boston arrival and departure times. Some adjustments were made to this to improve the utilization of operators and vehicles. In cases where volumes required more buses at any station than the present number of trains, departures would be staggered in order to provide more choice for users.

Most commuter bus routes were designed to serve existing commuting patterns as well as existing stations in order to take advantage of station parking lots and shelters. In addition, buses would stop along their path between town centers and expressways. These stops would reduce access distance for some users, and would partially compensate for the longer bus line-haul times. Analysis of the origins of rail users found several cases in which a large volume of park-riders would be better served by a new station site. Bus routes to serve these new stations were included in the bus network.

2.0 LINE DESCRIPTIONS

A total of 8 lines of existing commuter rail service have had alternative commuter bus services designed for analysis. These lines would require 243 buses daily excluding the spares (17.6 percent spares ratio required of 43 buses) to be used on about 100 bus routes covering the whole system (North and South). The assignment of buses to each line is shown in Table 2-1. Refer to section 3.0 for division of these bus services between the MBTA and private carriers.

Most Northside bus service would be terminated at Haymarket station and some would terminate in Post Office Square (Boston) or in Cambridge. Southside bus services would terminate in Copley Square or at South Station.

2.1 EASTERN ROUTE

2.1.1 Existing Transit Service

The MBTA operates several bus routes between North Shore communities and Haymarket Square in Boston. Route 400 runs from Haymarket Sq. to Central Sq., Lynn via Lynn Common. Most trips on this route continue to Salem via Loring Ave. as MBTA route 455. The route stops next to the commuter rail station in Lynn and passes near the Swampscott (within 500 ft.) and Salem (about 700 ft.) stations.

Route 440 runs from Haymarket Sq. to Central Sq. via General Edwards Bridge and serves Lynn Station directly. Most trips from #440 continue to Marblehead as Route 441 via Paradise Rd. or as Rte. 442 via Humphrey St. These two routes run within 1000 feet of Swampscott Station.

Route 450 runs from Haymarket Sq. to Salem via Western Ave. This is the fastest bus route between Boston and Salem wiht the Salem Terminal only about 1/4 mile from the railroad station. Some peak trips on #450 continue to North Bevelry as Route 451. At other times passengers for Beverly can transfer at Salem. However, neither railroad station in Beverly is served by peak service on Route 451.

Bus Routes	Total # of* Bus Routes	Number of Required Buses	Number of Spare Buses	Total # of Buses Assigned
Eastern Route	12	39	7	46
Reading	3	18	3	21
New Hampshire	11	33	6	39
Fitchburg	9	20	4	24
Framingham	6	18	3	21
Needham	11	24	4	28
Franklin	24	30	5	35
Shore Line	25	61	11	72
TOTAL	101	243	43	286

* Includes basic routes plus their variations.

COMMUTER BUS ROUTES

TABLE 2-1

2.1.2 Alternative Bus Service Analyzed

Assuming that both the Eastern Route Main Line to Ipswich and Gloucester Branch would be discontinued, a bus system composed of 12 routes was designed (Table 2-2). All routes would terminate in Boston with some operating during peak hours and others during off-peak hours only. ~~Most of these~~ routes would approach Boston via U.S. Route 1 and the Mystic-Tobin Bridge. Although I-93 is less congested than Route 1, the additional access time required cancels out the advantage of using I-93.

2.1.3 Detailed Route Description

This section describes the path that each bus route would follow plus the stations (underlined) that they would serve along their path. In addition a detailed schedule of each bus route is summarized in Table 2-2. The route descriptions follow:

#1 Rockport Station to Haymarket Station via Mass. Rte. 127A to Gloucester Station, Washington St., Mass. Rte. 128, Rte. 1 and the Mystic Bridge.

#2 Rockport Station to Haymarket Station via Rte. 127A, Gloucester Station, Rte. 127, Manchester Station, Pine St., Rte. 128, Rte. 1, and the Mystic Bridge.

#3 Rockport Station to Haymarket Station. Same as Route #4 to Gloucester Station and Manchester Station, then via Mass. 127 through Beverly Farms Station, and Prides Station to Corning St., Essex St., Montserrat Station, Brimball Ave., Rte. 128, Rte. 1, and the Mystic Bridge.

#3A Beverly Farms Station to Haymarket Station via Prides Station and Montserrat Station. This route is the same as Rte. 3 west of Beverly Farms.

#4 Manchester Station to Haymarket Station via Pine St., Rte. 128, Rte. 1, and the Mystic Bridge

#5 Beverly Station to Haymarket Station via Rantoul St., Mass Rte. 62, Rte. 128, Rte. 1 and the Mystic Bridge

#6 North Shore Shopping Center - Haymarket Station via Rte. 128, Rte. 1 and the Mystic Bridge. This route would provide supplementary service to Route #5 during peak hours only.

#7 Salem Station to Haymarket Station via Mass. Route 107 and McLellan Highway. This is similar to existing bus route 450, but would originate at Salem Station and make only limited stops.

	Rockport to Haymarket 1	Rockport to Haymarket 2	Rockport to Haymarket 3	Beverly Farms to Haymarket 3A	Manchester to Haymarket 4	Beverly to Haymarket 5	N. Shore Sh. Ctr. to Haymarket 6	Salem to Haymarket 7	Swampscott to Haymarket 8	Ipswich to Haymarket 9	Hamilton & Wenham to Haymarket 10	Ipswich to Haymarket 10A
Inbound Departure Times	6:12 6:42 7:12 4:30	8:13 10:27 1:27 5:39 8:00 10:00	5:07	6:31 7:01 7:31	6:40 7:10 7:40	5:25 5:55 6:20 6:45 7:03 7:16 7:26 7:37 7:45 8:05 8:45 hrly. until 10:45 PM	6:05 6:30 6:55 7:13 7:26 7:36 7:47	6:35 7:00 7:18 7:41 8:01 8:20	7:22 7:42 8:02	6:14 6:52 7:30	6:14 6:59 7:14 7:29 8:30	9:15 2:15 3:45
Outbound Departure Times	4:56 5:20 6:00	8:45 11:45 2:48 3:57 6:00* 8:00*		4:55 5:20 6:00	4:55 5:20	6:35 7:05 7:45 8:45 hrly. 3:45 4:20 4:40 5:00 5:20 5:30 6:00 6:45 hrly. until 9:45	4:20 4:40 5:00 5:20 5:30	4:20 4:40 5:00 5:20 5:30 6:00 6:30	4:40 5:00 5:20 5:30 6:00	4:30 5:00 5:30	7:25 5:00 5:30 6:30	8:10 1:00 2:30 6:30
Running Time From Term. Stn.	88	87	103	69	60	Pk-55 OffPk -45	45	40	38	66	56	58
Distance	38.5	39.5	39.8	26.5	28.4	23.1	17.8	15.5	11.3	31.5	24.8	30.8
# of Buses Required	5 for 1 thru 3			3	3	8	6	8 for 7 & 8		6 for 9 thru 10A		

*Bus runs to Gloucester only.

EASTERN ROUTE BUS SERVICE

TABLE 2-2

#8 Swampscott Station to Haymarket Station via Essex St., and General Edwards Bridge. This route is basically a short turn of Route 455, operating to Boston via Route 440.

#9 Ipswich Station to Haymarket Station via Mass. Rte. 133, U.S. Rte. 1, and the Mystic Bridge

#10 Hamilton and Wenham Station to Haymarket Station via Mass. Rte. 1A, North Beverly Station, Route 128 to Rte. 1 and the Mystic Bridge

#10A Ipswich Station to Haymarket Station via Rte. 1A, Hamilton and Wenham Station, North Beverly Station, Rte. 128, Rte. 1 and the Mystic Bridge

2.2 READING BRANCH

2.2.1 Existing Transit Service

At present there are no private carriers providing service to or toward Boston from Reading, Wakefield or Melrose, the three principal communities served by the Reading Line. The MBTA's Orange Line follows the Reading right-of-way and several MBTA bus routes (135/136/137) connect with the Orange Line at Oak Grove. This route runs along the Reading Route corridor to Reading and beyond. Only Greenwood Station and Wakefield Station are served directly by buses; at remaining stations the distance to the bus route varies from 500 to 2000 feet. Therefore, the bus line is beyond reasonable walking distance from homes west of the Reading Line at most points. Since there is very little excess capacity on Route 135/136/137 it could not accommodate most of the peak riders if commuter rail service were dropped. Frequency of service on these bus lines could be increased, but they do not provide close replacement service for most stations.

2.2.2 Alternative Bus Service Analyzed

Bus service for this corridor would consist of 3 routes running during morning and evening peak period only, excluding spares this service would require 18 buses.

2.2.3 Detailed Route Description

This section describes the path that each bus route would follow plus the stations (underlined) that they would serve along their path. In addition a detailed schedule of each bus route is summarized in Table 2-3. The route descriptions follow:

#1 Reading Station to Haymarket Station via I-93.

#2 Wakefield Station to Greenfield Station to Oak Grove Station via Main St.

#3 Melrose Highlands Station- Melrose Station, Wyoming Station to Oak Grove Station via Tremont, Essex, and Main Streets.

2.3 NEW HAMPSHIRE DIVISION

2.3.1 Existing Transit Service

Existing bus service on MBTA route #134 serves Winchester Station and indirectly Woburn and Cross St. Station. The route is over ½ mile from Wedgemere and over ½ mile from West Medford. Route 95 serves the W. Medford station and #133 funs from Woburn Sq. to Oak Grove. There are also 2 peak-period express routes serving this corridor: #326 rusn from W. Medford to Haymarket and #701 runs from Burlington via Woburn to Boston. In addition #136 runs from Wilmington to Malden Station via Reading and Wakefield. Trombly Motor Coach also operates bus service from Lowell and Haverhill to Boston.

2.3.2 Alternative Bus Service Analyzed

Replacement service on this line would consist of 10 new bus routes plus increased service on existing bus route 134 w. If all routes were run by the MBTA a total of 33 buses would be needed.

2.3.3 Detailed Route Description

This section describes the path each bus route would follow plus the stations (underlined) that they serve. In addition a detailed schedule of each bus route is shown in Table 2-4. The route descriptions follow:

#1 Lowell Station to Haymarket Station via the Lowell connector, U.S. Route 3, Route 128 and I-93.

#2 I-495 Station to Haymarket Station -- supplement to Route #1 -- originates at park-and-ride lot at junction of I-495 and U.S. Route 3.

#3 North Billerica Station to Haymarket Station via U.S. Route 3, Route 128 and I-93.

#4 Lowell Station to Haymarket Station via N. Billerica Station. This route would be an off-peak combination of Routes #1 and #3.

	1 Reading to Haymarket	2 Wakefield to Oak Grove	3 Melrose Highlands to Oak Grove
Inbound Departure Times	6:30 6:45 7:00 every ten min. 8:30 8:45 9:45	6:45 7:00 7:10 7:20 7:30 7:40 8:10 8:20 8:30	6:45 7:00 7:10 7:20 7:30 7:40 8:10 8:20 8:30
Outbound Departure Times	4:00 4:15 4:30 every ten min. 6:00 6:15 7:15	4:30 4:45 every ten min. 6:05	4:30 4:45 every ten min. 6:05
Running Time From Term. Stn.	34	36	27
Distance	12.7	4.8	2.0
# of Buses Required	9	5	4

READING BRANCH BUS SERVICE

TABLE 2-3

#5 Wilmington Station to Haymarket Station via Main Street, Lowell Street and I-93.

#6 Woburn Station to Haymarket Station. This route would be a short-turn of existing bus route 701, starting at Woburn Station

#7 Cross Street Station to Haymarket Station via Woburn Station. This route is an extension of Route #6, running from Cross Street to Woburn via Main Street.

#8 Winchester Station to Haymarket Station via Massachusetts Routes 38, 60 and I-93.

#9 Cross Street Station to Haymarket Station via Winchester Station. This route is an extension of Route #8.

#10 Wedgemere Station to Haymarket Station via Bacon Street and Routes 38, 60 and I-93.

#11 Winchester Station to Wellington Station via Main St. This route would consist of an extension of existing bus route 134W. Service on this route now runs from Wellington to Playstead Road in Medford on an hourly headway.

2.4 FITCHBURG ROUTE

2.4.1 Existing Transit

The MBTA provides bus service to several points on the Fitchburg Line within Rte 128, but not to any points beyond, where most of the riders on the line originate. Bus route 74 runs from Belmont Center to Harvard Square, serving Belmont Station directly. Mid-day trips operate beyond Belmont to Waverly. Trackless trolley route 73 runs from Waverly Sq. to Harvard serving Waverly Station directly. Bus route 523 runs from Stow St., Waltham to Central Sq., Cambridge passing within 1,000 feet of Waltham Station. Route 521 runs from Newton Corner to Waverly, passing within 500 feet of Waltham Station. Passengers can transfer at Waverly to Rte 73, or at Newton Corner to express buses for Boston. Bus route 520 runs from Roberts Station to Newton Corner, passing within 500 feet of Waltham Station. Service from Waltham to Newton Corner is also provided by bus routes 522 and 527. Express bus route 305 runs from Central Sq., Waltham to downtown Boston via the Mass. Turnpike. This route passes within 500 feet of Waltham Station.

Outside Route 128, the only bus service in the Fitchburg Route corridor is a route operated by Englander Coach Lines between Fitchburg and Park Sq., Boston. Buses on this line stop on Route 2 in West Concord. This stop is about one mile from the W. Concord railroad Station.

	Lowell to Haymarket	I-495 to Haymarket	N. Billerica to Haymarket	Lowell to Haymarket	Wilmington to Haymarket	Woburn to Haymarket	Cross St. to Haymarket	Winchester to Haymarket	Cross Street to Haymarket	Wedgemere to Haymarket	Winchester to Wellington
	1	2	3	4	5	6	7	8	9	10	11
Inbound Departure Times	6:21 6:41 7:06 7:26 7:46 3:10 4:10 5:00	6:33 7:08 7:38	6:30 6:50 7:15 7:35 7:55 5:30	8:36 9:16 10:16 11:16 12:16 1:16 2:16 5:46 6:56 8:45	6:36 7:10 7:30 7:50 8:10 2:50 3:50 4:50 5:37	7:05 7:40 8:05 8:25 2:00 3:10 4:25		6:43 7:28 7:43 8:08 2:15 3:15 4:15 4:50 5:10 7:55	7:03 7:38 8:03 8:23 4:50	7:09 7:29 7:44 8:09 8:29 4:45 5:05 5:30	9:00 hrly. 1:00 7:00 hrly. 10:00
Outbound Departure Times	2:10 3:10 4:10 4:45 5:00 5:15 5:30 6:10	4:10 5:00 5:30	7:15 4:45 5:00 5:15 5:30 6:10	9:30 11:10 12:10 1:10 2:10 3:10 6:50 7:50 9:30	2:10 3:10 4:10 4:45 5:00 5:15 5:30 6:10	1:10 2:40 3:40 4:15 4:35 5:10 7:20	5:35 6:00 10:00	7:15 1:40 2:40 3:40 4:15 4:35 5:00 5:15 5:20 5:35 6:00 7:20 10:00 10:30	7:45 4:15 5:10	7:40 8:00 4:15 4:35 5:00 5:15 5:35 6:00 10:30	8:30 hrly. 12:30 6:30 hrly. 9:30
Running Time From Term. Stn.	44	42	35	44	27	25	29	22	27	21	
Distance	30.1	27.7	24.3	30.3	16.3	11.6	12.7	7.5	8.5	7.3	
# of Buses Required	14 for 1 thru 4				5	14 for 6 thru 10					0

NEW HAMPSHIRE DIVISION BUS SERVICE

TABLE 2-4

2.4.2 Alternative Bus Service Analyzed

A commuter bus service was designed to serve the Fitchburg Corridor assuming that the Red Line would be extended to Alewife and that Alewife station would be used as an inbound terminal for the buses on this line. Replacement service on this line would consist of 9 new bus routes plus increased service on the existing bus route number 305. If all routes were run by the MBTA a total of 20 buses would be needed. Once the Red Line is extended to Alewife this station would be the termination point for these routes. Under this system rive routes would run to Alewife, serving S. Acton, W. Concord, and Concord. Running times would be reduced by 23 minutes, one-way trip lengths by 12 miles. Including use of the Red Line, total trip time to Haymarket would be reduced by 5 minutes as compared to the first system. An additional route would provide off-peak service to Alewife from Cambridge, S. Acton, W. Concord, and Concord reducing one-way mileage by 2.2 miles and one-way time by 9 minutes. Another route serving Lincoln and Kendall Green Stations was split into two routes: 1) service from Lincoln to Alewife and 2) reduced service from Kendall Green to Boston. Travel time from Lincoln to Boston would be 2 minutes less via Alewife than direct service to Boston while travel times from Kendall Green to Washington would not change. Service from Roberts to Harvard Sq. would remain intact. Increased frequencies on #305 would still be used to provide service to Waltham Station.

2.4.3 Detailed Route Description

This section describes the path that each bus route would follow plus the stations (underlined) that they would serve along their path. In addition a detailed schedule of each bus route is summarized in Table 2-5. The route descriptions follow:

#1 <u>South Acton Station</u> - <u>Alewife Station*</u> via Routes 27 and 2, Alewife Brook Parkway.

#2 <u>West Concord Station</u> - <u>Alewife Station*</u>, via Routes 62 and 2 , then as #1.

#3 <u>South Acton Station</u> - <u>Alewife Station*</u>, via Thoreau Street, Walden Street to Route 2, then same as #1.

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* Alewife Station is a proposed station on the Red Line extension to Alewife and is not in existence at the present time.

#4 Concord Station - Alewife Station, via Thoreau Street, Walden Street to Route 2, then same as #1.

#5 West Concord Station - Alewife Station*, via Route 62, Concord Station, then same as #4.

#6 South Acton Station - Alewife Station*, via Routes 27, 111 and 2, Commonwealth Avenue, W. Concord Station, Route 62, Concord Station, Route 2, Alewife Brook Parkway.

#7 Lincoln Station - Alewife Station*, via Routes 117, 128, and 2, Alewife Brook Parkway.

#8 Kendall Green Station - Haymarket Square Station, via Routes 117, 128, Massachusetts Turnpike Extension, Kneeland Street, Atlantic Avenue, Federal Street and Congress.

#9 Roberts Station - Harvard Square, via South Street, River Road, the Massachusetts Turnpike to Beacon Park interchange, Western Avenue, N. Harvard Street and Boylston Street.

#305 Additional bus service on Waltham Express - Central Square, Waltham to Summer and Chauncey Street intersection.

2.5 FRAMINGHAM LINE

2.5.1 Existing Transit Services

MBTA #531 Framingham Station to Newton Corner (some trips in the peak run through to Boston). This route serves Framingham through Newtonville Station. Total travel time exceeds that of rail. The route also connects with the Green Line at Woodland Station.

MBTA #305 Waltham-Boston passes within 2 blocks of Auburndale Station. Bus running time is 20 minutes to South Station compared to 24 minutes for rail.

Gray Line - express bus service is provided from Shoppers World, Framingham to Park Square with a running time of 25 minutes . Rail running time is 50 minutes.

Wellesley Fells operates service from Framingham to Park Square. Routes pass within a few blocks of Wellesley Hills Station. Bus running time is 65-70 minutes while rail time from Framingham to South Station service is also offered. Once again bus time (50 min.) exceeds rail service (42 min.) from Natick to Park Square.

	S. Acton to Alewife **	W. Concord to Alewife	S. Acton to Alewife	Concord to Alewife	W. Concord to Alewife	S. Acton to Alewife	Lincoln to Alewife	Kendall Green to Haymarket	Roberts to Harvard Sq.	Addition to Waltham Express
	1	2	3	4	5	6	7	8	9	305
Inbound Departure Times	6:35 7:05 7:25 7:40 5:05	7:10 7:25 7:40	7:55	7:15 7:30 7:45 8:00 8:15	6:35	8:30 9:30 10:30 12:00 1:30 3:00 4:00	6:50 7:05 7:20 7:35 7:50 8:15 8:50 9:50 5:40	7:27 7:57	6:36 7:06 8:06 9:06 10:06 11:36 12:36 2:06 4:06 5:36	two additional trips
Outbound Departure Times	5:12 5:32 5:42 5:52	5:25 5:40 5:55	6:22	5:06 5:21 5:36 5:51 6:21		7:45* 8:45* 9:30 10:30 12:30 2:00 3:00 4:00	5:08 5:33 5:48 6:18 6:58 10:18	5:00 5:30	7:06 7:36 8:36 9:36 11:06 12:06 1:06 2:36 3:36 5:00	two additional trips
Running Time From Term. Stn.	33	25	38	24	30	43	22	33	24	26
Distance	19.5	14.6	19.9	13.4	15.1	20.3	12.0	16.9	11.8	
# of Buses Required	4	3	0	4	0	0	4	2	1	2

*Express bus, S. Acton - Alewife

**Alewife Station is a proposed station on the Red Line Extension

FITCHBURG ROUTE BUS SERVICE

TABLE 2-5

2.5.2 Alternative Bus Service Analyzed

Initially it was assumed that most replacement service in this corridor would be provided by existing private carrier and MBTA routes. Re-examination of ridership in this corridor indicated the need for specific replacement services. Consequently six bus routes were designed with each route having one departure for each train discontinued.

2.5.3 Detailed Route Description

This section describes the path that each bus route would follow plus the station (underlined) that they would serve along their path. In addition a detailed schedule of each bus route is summarized in Table 2-6. The route descriptions follow:

#1 Framingham Station to South Station via Route 135 to Natick Station and Routes 27 and 9, Speen Street and the Massachusetts Turnpike to South Station.

#2 Same route as #1, except that it would terminate in Copley Square instead of South Station.

#3 Wellesley Station to South Station via Route 16 to Wellesley Hills Station, then 128 and the Massachusetts Turnpike to South Station.

#4 Same route as #3, terminating in Copley Square instead of South Station.

#5 Wellesley Farms Station - Copley Square - South Station via Glen Road, Route 16, Route 128 and the Massachusetts Turnpike to Copley Square, then Stuart and Kneeland Streets to South Station.

#6 Auburndale Square Station - South Station via Commonwealth Avenue and Washington Street past West Newton and Newtonville to Newton Corner, then via the Massachusetts Turnpike to South Station. At Newton Corner riders could transfer to MBTA #302 to reach Copley Square.

2.6 NEEDHAM BRANCH

2.6.1 Existing Transit Service

At the present time there is no alternate through transit service to downtown from any stations on the Needham Branch except Forest Hills.

	1 Framingham to South Station	2 Framingham to Copley Square	3 Wellesley to South Station	4 Wellesley to Copley Square	5 Wellesley Farm to Copley Square to South Station	6 Auburndale Sq. to South Station
Inbound Departure Times	7:10 7:35 7:50	7:07 7:32 7:47	7:25 7:50 8:05	7:22 7:47 8:02	7:16 7:41 7:56	7:23 7:48 8:03
Outbound Departure Times	4:46 5:16 5:46 7:10	4:48 5:18 5:48 7:12	4:49 5:19 5:49 7:13	4:51 5:21 5:51 7:15	4:33 5:03 5:33 6:56	4:35 5:05 5:35
Running Time From Term. Stn.	45	43	30	28	23/39	32
Distance	26.0	25.2	16.6	15.8	15.0	10.7
# of Buses Required	3	3	3	3	3	3

FRAMINGHAM ROUTE BUS SERVICE

TABLE 2-6

MBTA bus routes 35, 36 and 37 parallel the Needham Branch from Forest Hills to West Roxbury. All three routes pass Roslindale and Bellevue Station and run close to Highland and West Roxbury (within 600 feet). Service on these routes is coordinated to provide peak headways of about 6 minutes and off peak headways of 10 minutes between West Roxbury and Forest Hills.

The MBTA provides no alternate service at the Bird's Hill or Needham Jct. Stations. A private carrier, Needham Transit Co., now operated by Metropolitan Coach Service holds operating rights for a bus route from Needham Center to the Charles River Loop MBTA terminal via Bird's Hill Station. Due to a lack of patronage only one trip is offered in the morning.

MBTA route 522 runs from Needham Center to Watertown connecting with the Green Line at Newton Highlands. This route starts near the Needham railroad station, and passes the Needham Heights Station. While it is true that someone could travel to downtown by using this route, it is a long and unlikely alternative for most travellers.

2.6.2 Alternative Bus Service Analyzed

The bus service assumed for the Needham Branch replacement is essentially the same service that was used for temporary replacement during the transition from Conrail to B&M operation. It may differ somewhat from the replacement service that will actually be used when rail service is discontinued in conjunction with the Orange Line reconstruction.

The service consists of express buses to Copley Square and South Station from the four Needham stations during rush hours and a shuttle bus from these stations to Riverside on the Green Line during mid-day. There are a number of routing variations for the Needham express bus service, including separate service to Copley Square and South Station, combined service to both stations, separate service from Bird's Hill and combined service to all Needham Stations. In addition a short-turn bus operating on 10-minute-headways from West Roxbury to Forest Hills would be operated during morning andevening peak hours. If ridership warrants it, this route could be extended to Boston.

2.6.3 Detailed Route Description

This section describes the path that each bus route would follow plus the stations (underlined) that they would serve along their path. The following bus routes are

preliminary and is expected to be revised at a later date. In addition Table 2-7 shows the AM peak schedule of these bus routes and on the PM peak there would be a similar schedule with lesser trips. The route descriptions follow:

#1 Needham Junction Station to Copley Square via Chestnut Street, Needham Station, Highland Avenue, Needham Heights Station, Highland Avenue to Route 128 and Massachusetts Turnpike.

#2 Needham Heights Station to Copley Square via Highland Avenue to Route 128 and Massachusetts Turnpike.

#3 Needham Junction Station to Copley Square via Chestnut Street, Highland Avenue to Route 128 and Massachusetts Turnpike.

#4 Bird's Hill Station to Copley Square via Great Plain Avenue, to Route 128 and Massachusetts Turnpike.

#5 Needham Station to Copley Square via Highland Avenue, Needham Heights Station, Highland Ave. to Route 128 and Massachusetts Turnpike.

#6 West Roxbury Station to Copley Square via Centre Street, Highland Station, Centre Street to Jamaicaway South Huntington and Huntington Avenue.

#7 West Roxbury Station to Copley Square via Centre Street to Jamaicaway, S. Huntington and Huntington Ave.

#8 Bellevue Station to Copley Square via Belgrade Ave. Roslindale Station, Jamaicaway to S. Huntington and Huntington Avenue.

#9 Highland Station to Copley Square via Centre Street, Bellevue station and then same as route #8 to Copley Square.

#10 Highland Station to Copley Square via Centre Street, Bellevue Station, Jamaicaway to S. Huntington and Huntington Avenue.

#11 Roslindale Station to Copley Square via Jamaicaway to to S. Huntington and Huntington Avenue.

2.7 FRANKLIN BRANCH

2.7.1 Existing Transit Service

Existing transit alternatives - MBTA bus route 31, Wolcott Sq. to Mattapan passes within 500 feet of Readville Station.

	1 Needham Jct. to Copley Square	2 Needham Heights to Copley Square	3 Needham Jct. to Copley Square	4 Bird's Hill to Copley Square	5 Needham to Copley Square	6 West Roxbury to Copley Square	7 West Roxbiry to Copley Square	8 Bellevue to Copley Square	9 Highland to Copley Square	10 Highland to Copley Square	11 Roslindale to Copley Square
Inbound Departure Times	6:44 8:39	7:25	7:31 7:54 8:20	7:34 7:47 8:23	7:48 8:14	6:59	7:40 8:03 8:29	7:05	7:42	8:05	8:11
Outbound Departure Times*											
Running Time From Term. Stn.	48	36	45	42	42	59	59	59	57	56	52
Distance	17.6	16.0	16.8	15.9	16.1	8.5	8.0	7.0	8.0	8.0	6.5
# of Buses Required	15 buses for 1 through 5					9 buses for 6 through 11					

* Outbound Departure Times (not tabulized at this time) are similar type schedule as Inbound Departure Times with a slight reduction in service.

NEEDHAM BRANCH BUS SERVICE

TABLE 2-7

Bus route 34E, East Walpole to Forest Hills passes within 800 feet of Norwood Central and Norwood Stations but is at least 1/4 mile from all other stations on the line.

Hudson Bus Lines, Inc. operates two routes in Dedham connecting Endicott Station with MBTA bus route 34E. ABC, Inc. operates a route from Providence, Rhode Island to the Boston Greyhound Station passing through Walpole, Norwood, Westwood, and Dedham. This route passes within 1,000 feet of Walpole and Norwood Central Station and within 800 feet of Norwood Station. This route also passes the Windsor Gardens development on the opposite side from the railroad. Operating rights for this route originally contained restrictions on passenger pick-up points in order to prevent competition with the railroad and with bus route 34E. The current status of restrictions should be reviewed.

2.7.2. Alternative Bus Service Analyzed

Replacement service for this corridor would consist of 10 new bus routes most of which have short-turn variations. The large number of routings compared to the number of stations was necessary in order to maintain reasonable load factors while attempting to minimize travel time. Thirty buses would be needed to operate this service.

2.7.3 Detailed Route Description

This section describes the path that each bus route would follow plus the stations (underlined) that they would serve along their path. In addition a detailed schedule of each bus route is summarized in Table 2-8. The route descriptions follow.

#1 Franklin Station to South Station only via East Central Street, I-495, the Massachusetts Turnpike, Kneeland Street and Atlantic Avenue.

#1A The same as #1, except the route would terminate at Copley Square.

#1B The same as #1, but serves both South Station and Copley Square. Buses would leave the Massachusetts Turnpike at the Copley exit and run to South Station via Stuart and Kneeland Streets.

#2 Norfolk Station to Copley Square and South Station via Massachusetts Routes 115, 109, 128, the Massachusetts Turnpike, Stuart Street, Kneeland Street, and Atlantic Avenue.

#3 Walpole Station to South Station via Massachusetts Route 1A (past Windsor Gardens), Chapel Street, Washington Street, E. Hoyle Street. Norwood Central, Broadway, Nahatan Street (near Norwood), U.S. Route 1, Massachusetts Route 128, the Massachusetts Turnpike, Kneeland Street and Atlantic Avenue.

#3A Norwood Central Station to South Station - short-turn from Norwood Central using the routing of #3.

#3B Norwood Station to South Station following routing for #3. This route would be operated if the Norwood Central short turns generated full bus loads at Norwood Central.

#4 Walpole Station to Copley Square via Norwood Central Station. This route would be similar to #3, except that buses would leave the Massachusetts Turnpike and terminate at Copley Square.

#4A Windsor Gardens Station to Copley Square.

#4B Norwood Central Station to Copley Square.

#5 Walpole Station to Copley Square and South Station via Norwood Central Station. This route would be similar to Route #4, except that buses would continue beyond Copley Square to South Station via Stuart Street, Kneeland Street and Atlantic Avenue, returning via St. James Avenue

#5A South Station to Norwood Central via Copley Square.

#5B Norwood Station to South Station.

#6 Walpole Station to South Station, by-passing Norwood Central. This route would be similar to Route #3, except that buses would follow Massachusetts Route 1A to Nahatan Street, to U.S. Route 1.

#6A Windsor Gardens Station to South Station.

#6B Walpole Station to Copley Square.

#7 Windsor Gardens Station to Copley Sq. and South Station via Massachusetts Route 1A, Chapel Street, Washington Street, E. Hoyle Street, Norwood Central, Broadway, Nahatan Street (near Norwood), Washington Street past Islington Post Office, Elm Street, U.S. Route 1, Massachusetts Route 128 and the Massachusetts Turnpike Extension.

	Franklin to South Station	Franklin to Copley Square	Franklin to Copley Square to South Station	Norfolk to Copley to South Station	Walpole to South Station	Norwood to South Station	Norwood to South Station	Walpole to Copley Square	Windsor Gardens to Copley Square	Norwood Central to Copley Square	Walpole to Copley to South Station	South Station to Copley to Norwood Central
	1	1A	1B	2	3	3A	3B	4	4A	4B	5	5A
Inbound Departure Times	7:01 7:16	7:11	5:58 9:36 5:30	6:02 7:05	6:14	7:30 7:40 7:55	7:36 7:58	6:11		7:31		
Outbound Departure Times	4:05 5:00 5:15	8:20 5:17	4:03 6:50	4:03 5:17	4:03	8:50 5:10 5:20	4:55 5:10 5:20	4:08	5:22		2:30	5:37
Running Time From Term. Stn.	59	57	72	68	56	40	37	54	38	37	69	53
Distance	44.2	44.0	44.7	34.6	30.9	26.2	25.9	30.1		25.9	31.4	26.7
# of Buses Required	5 for 1 thru 1B (if run separately from other services)			2	17 for 3 thru 9 (5B - 9 on p.2 of Table 2-7)							

FRANKLIN ROUTE BUS SERVICE

TABLE 2-8
P.1

	Norwood to South Station	Walpole to South Station	Windsor Gardens to South Station	Walpole to Copley Square	Windsor Gardens to Copley to South Station	Islington Post Office to South Station	Norwood to South Station	South Station to Islington Post Office	Norwood to Copley Square	Endicott to South Station	Endicott to Copley Square	Endicott to Copley Square to South Station
	5B	6*	6A	6B*	7	7A	8	8A	9	10	10A	10B
Inbound Departure Times	9:58	7:20 4:00	7:27	7:17	8:18	7:19 7:46				6:34 7:34 7:44 7:59 6:05	6:32 7:35 8:02 4:00	
Outbound Departure Times		5:17	7:20 5:15 5:30	5:22	6:50		4:00 5:40	5:17	5:22	5:17 5:37	7:10 7:20 5:17	2:30 4:03
Running Time From Term. Stn.	50	53	46	51	70	49	45	36	43	36	33	49
Distance	26.4	30.6	28.0	29.8	29.9	23.5	25.0	23.0	23.5	23.3	22.5	23.8
# of Buses Required	17 for 3 thru 9 (3 - 5A on p.1 of Table 2-7)									6 for 10 thru 10B		

*no stop at Norwood Central

FRANKLIN ROUTE BUS SERVICE

TABLE 2-8 P.2

#7A Islington Post Office to South Station.

#8 Norwood - South Station via Islington. This route would be similar to Route #7, but would start at Broadway and Nahatan Street and would not serve Copley Square.

#8A South Station to Islington Post Office.

#9 Norwood Station to Copley Square via Islington. This route would be similar to Route #8, but would terminate at Copley Square instead of South Station.

#10 Endicott Station to South Station via East Street, Massachusetts Route 128, the Massachusetts Turnpike, Kneeland Street and Atlantic Avenue.

#10A The same as Route #10, except that service would terminate at Copley Square.

#10B The same as Route #10, except that both Copley Square and South Station would be served.

2.8 SHORE LINE

2.8.1 Existing Transit Service

Existing transit alternatives - Mount Hope Station is served directly by MBTA bus routes 32 and 28 to Forest Hills. Hyde Park Station is about 300 feet from Cleary Sq., which is served by MBTA bus route 32 to Forest Hills and Routes 31 and 33 to Mattapan. Bus route 50 to Forest Hills terminates 300 feet to the west of the railroad station. Readville Station is within 500 feet of Wolcott Square, which is served by MBTA bus route 31 to Mattapan. The stations listed above are the only stations on the Providence Line with alternate MBTA service.

In Spring 1977 Hudson Bus Lines started an express bus route from Rte. 128 Station to downtown Boston via the Southeast Expressway. The purpose of this route was to reduce congestion on the expressway during reconstruction work, but the route attracted few riders.

Brush Hill Transportation Co. operates a bus line from Stoughton Center, near the railroad station, to the Mattapan MBTA station.

Bonanza Bus Lines operates an express route from downtown Providence to the Boston Greyhound terminal via Interstate 95. Buses on some trips stop in Pawtucket just off I-95.

ABC, Inc. operates a bus route from Providence to Boston via U.S. Route 1, Mass. Route 1A. These buses stop in Pawtucket and in North and South Attleboro. The latter two stops are both several miles from the Attleboro railroad station.

2.8.2 Alternative Bus Service Analyzed

In designing bus service for the Shore Line and Stoughton Branch it was assumed that service to points in Rhode Island was not the responsibility of the MBTA or the State. Bonanza Bus Lines could expand service from Providence to Boston as necessary to meet additional demand if commuter rail service were dropped. The replacement service in this corridor consists of 10 basic routes with some variations. Sixty-one buses would be needed for this service.

2.8.3 Detailed Route Description

This section describes the path that each bus route would follow plus the stations (underlined) that they would serve along their path for both Shore Line and Stoughton Branch. In addition a detailed schedule of each bus route is summarized in Table 2-9. The route descriptions follow:

#1 Attleboro Station to South Station via Massachusetts Route 123, I-95, Route 128, the Massachusetts Turnpike Extension, Kneeland Street and Atlantic Avenue.

#1A Attleboro Station to Copley Square. Same routing as #1.

#1B Attleboro Station to South Station, then via St. James Avenue to Copley Square. Same routing as #1, except entrance to Boston would be via the Southeast Expressway.

#1C Attleboro Station to Copley Square, then South Station. Routing is similar to #1B, except that buses would use the Massachusetts Turnpike.

#2 Mansfield Station to South Station via Massachusetts Routes 106 and 140, I-95, Route 128 and the Massachusetts Turnpike Extension.

#2A Mansfield Station to Copley Square. Same routing as #2.

#2B Mansfield Station to South Station, then Copley Sq. Same routing as #2, but approaching Boston via Southeast Expressway.

#3 Sharon Station to South Station via Massachusetts Route 27, I-95, Route 128 and the Massachusetts Turnpike Extension.

#3A Sharon Station to Copley Square. Same routing as #3.

#3B Sharon Station to South Station, then Copley Square. Same routing as #3, except buses would enter Boston via Expressway.

#4 Mansfield Station to South Station via Massachusetts Routes 106 and 140, I-95 to exit 8, South Main Street, Depot Street, Sharon Station, Massachusetts Route 27, I-95, Route 128 and the Southeast Expressway.

#4A Manfield Station to South Station, then Copley Square. This route is the same as #4, except buses continue beyond South Station to Copley via Kneeland Street and St. James Avenue.

#5 Canton Junction Station to South Station via Beaumont, Spaulding, Chapman and Neponset Streets, I-95, Route 128, and the Massachusetts Turnpike.

#5A Canton Junction Station to Copley Square. Routing is the same as #5, except for termination point.

#5B Canton Junction Station to South Station and Copley Square. The same routing as #5, except the buses would approach Boston via the Expressway.

#6 Canton Center Station to South Station via Washington and Sherman Streets to Canton Junction Station, then the same as Route #5.

#6A Canton Center Station to Copley Square. The same routing as #6, except for the termination point.

#7 Stoughton Station to South Station via Massachusetts Routes 139, 24, 128 and the Southeast Expressway.

#7A Stoughton Station to Copley Square via Routes 139, 24 128 and the Massachusetts Turnpike.

#8 Stoughton Station to Copley Square via Massachusetts Route 27, Bay Street and Canton Center Station, then same as #6A to Copley Square.

#9 Route 128 Station to South Station via Access Road, Route 128 and the Massachusetts Turnpike.

#9A Route 128 Station to Copley Square with the same routing as #9.

#9B Route 128 Station to South Station to Copley Square. Same routing as #9, except buses would approach Boston via the Southeast Expressway.

#10 Readville Station to Forest Hills Station via Hyde Park Avenue, with stops at Hyde Park Station and Mount Hope Station.

#10A Hyde Park Station to Forest Hills Station via Hyde Park Avenue.

	Attleboro to South Station	Attleboro to Copley Square	Attleboro to South Station to Copley Sq.	Attleboro to Copley Sq. to South Station	Mansfield to South Staiton	Mansfield to Copley Square	Mansfield to South Station to Copley Sq.	Sharon to South Station	Sharon to Copley Square	Sharon to South Station to Copley Sq.	Mansfield to South Station	Mansfield to South Station to Copley Sq.	Canton Junction to South Station
	1	1A	1B	1C	2	2A	2B	3	3A	3B	4	4A	4B
Inbound Departure Times	6:00 7:05 7:20 7:40 5:22*	5:58 7:03 7:38	8:16 10:46		6:07 6:32 6:52 7:07 7:22 7:37 7:52 3:40	6:14 7:19 7:34 7:54 4:00 5:00 5:30	8:27 8:57	6:22 7:17 7:27 7:32 7:37 7:47 8:02	6:19 7:19 7:34 7:59 4:50	8:37 9:07 11:07 3:20		9:23 9:48 10:58 1:03	6:24 6:49 7:04 7:19 7:29 7:39 4:40 5:40
Outbound Departure Times	4:35 5:05 5:25	4:40 5:10	2:20 3:50 6:45	5:40	7:15 7:40 8:30 4:15 every 15 min. 5:45	8:20 8:35 4:30 4:50 5:10 5:30 6:00	2:30 3:45 6:45	4:35 4:45 5:00 5:10 5:20 5:35 5:45 6:45**	7:15 8:15 4:35 5:10 5:25 5:40 9:45	9:45 2:15 3:45	9:45 p.m.	9:05 11:15 12:20	3:45 4:30 4:45 5:00 5:10 5:20 5:30 5:50 6:45
Running Time Fr. Terminal Station	65	62	74	78	53	51	63	43	41	53	55	72	41
Distance	48.4	47.6	43.2	48.9	39.7	38.9	34.5	31.4	30.6	26.2	34.0	35.3	28.8
# of Buses Req.	8 for 1 thru 1C				12 for 2 thru 2B			11 for 3 thru 4A					***

*runs via Southeast Expressway (65 min.)

**runs via Southeast Expressway (36 min., 29.9 miles)

***13 buses required for 5 thru 6A (see p.2 of this table for 5A - 6A)

SHORE LINE AND STOUGHTON BRANCH BUS SERVICE

TABLE 2-9
P.1

	Canton Junction to Copley Square	Canton Junction to South Station to Copley	Canton Center to South Station	Canton Center to South Station	Stoughton to South Station	Stoughton to Copley Square	Stoughton to Copley Sq.	Route 128 to South Station	Route 128 to Copley Square	Route 128 to South Station to Copley	Readville to Forest Hills	Hyde Park to Forest Hills
	5A	5B	6	6A	7	7A	8	9	9A	9B	10	10A
Inbound Departure Times	6:22 6:52 7:22	9:10 7:12 7:32 8:12	6:52	7:30	6:42 6:57 7:12 7:27 7:42 8:12	7:22 7:37	6:39 7:59	6:32 7:02 7:17 7:42 8:12	6:59 8:09	8:46 9:51	6:30 7:30 8:00 8:15	8:15
Outbound Departure Times	7:15 3:50 4:35	8:10 2:20	5:15	5:20	5:00 5:10 5:20 5:30 5:50	5:10 5:25	5:50	4:35 5:10 6:45	4:40 5:15	2:15 3:50 5:40	5:00 5:40	6:00
Running Time From Term. Stn.	38	50	43	40	48	48	51	33	31	44	18	13
Distance	28.0	24.0	29.6	28.8	21.5	34.3	32.8	24.3	23.5	24.7	4.5	3.3
# of Buses Required	13 for 5 thru 6A*				9 for 7 thru 8			5 for 9 thru 9B			3 for 10-10A	

*5 is on page 1 of Table 1-7.

SHORE LINE AND STOUGHTON BRANCH BUS SERVICE

TABLE 2-9 P.2

3.0 DIVISION OF COMMUTER BUS SERVICE BETWEEN THE MBTA AND PRIVATE CARRIERS

3.1 LEGAL AND REGULATORY ISSUES

3.1.1 Routes Inside the MBTA District

Division of commuter rail replacement service between the MBTA and private carriers would be determined partly by MBTA management, but in some cases use of private carriers would be required by the Chapter 161A of the Massachusetts General Laws, commonly known as the MBTA Act. Section (i) of the Act authorizes the MBTA to operate service within its district without being subject ro regulation by the Department of Public Utilities (DPU). Section 5(k) of the Act states that "whenever the Authority desires to add new routes for service in any area, it shall give preference in the operation of such routes to the private carrier then serving such area, unless the Authority concludes that such carrier has not demonstrated an ability to render such service according to the standards of the Authority, that such service can be operated directly by the Authority at substantially lesser expense to the Authority and the public than if operated by such private carrier, or that for substantial and compelling reasons in the public interest operation by such private carrier is not feasible."

The MBTA has higher unit operating costs than any private carrier in the district. Consequently, the only situation in which MBTA could operate new service at lower expense than a private carrier would be one in which MBTA operation would require minor modification of existing service, but private carrier operation would require an entirely new route. It appears, then, that in any case where a private carrier were willing and able to operate a replacement route, this service would not be operated directly by the MBTA.

Unless a private carrier already held operating rights for proposed replacement service, it would have to obtain local licenses and an MBTA certificate for the service. The MBTA could attach certian stipulations to a certificate to ensure that the service met acceptable standards. Given the economics of mass transit service,

much of the proposed replacement service network would probably require operating subsidies, even if run by private carriers. Subsidy contracts would provide a mechanism for controlling the level of service run by private carriers.

3.1.2 Routes Outside the MBTA District

Section 3(j) of the MBTA Act permits the MBTA to "operate mass transportation facilities and equipment, directly or under contract, in areas outside the area constituting the authority; but only pursuant to (i) an agreement with or purchase of a private mass transportation company, part of whose operations were, at the time the authority was established, within the area constituting the authority or (ii) an agreement with a transportation area or a municipality for service between the area of the authority and that of such transportation area or municipality, where no private company is otherwise providing such service."

Because of high MBTA operating costs, areas outside the MBTA district would generally be able to contract with private carriers at lower cost. In some cases, however, the minimum cost option might be extension of MBTA routes from points within the district rather than operation of entirely separate service to Boston.

Existing commuter rial lines serve ten communities outside the MBTA district: Rockport, Gloucester, Ipswich, Lowell, Billerica, Acton, Franklin, Mansfield, Attleboro and Stoughton. Decisions as to replace service for these communities would be made by thier local governments, or Regional Transit Authorities. The state has historically paid a major share of the cost of rail service subsidies for the outside communities, but it is unclear whether aid for replacement bus service would be provided.

3.1.3 Legal Standing of School Bus and Charter Operators

Within the MBTA district there are several bus companies that provide school bus or charter service but not fixed route service. It appears that Section 5(k) of the MBTA Act does not require the MBTA to consider such carriers when establishing new service, but some of them might prove to be qualified operators for replacement service. At least two present fixed route carriers, Ritchie Bus Lines and Wellesley Fells Bus Lines were originally school bus operators, and the Gray Line, Inc. was originally in the sight-seeing business. Carriers without fixed routes should, therefore, be considered as candidates for replacement service operation.

3.2 SUMMARY

If the entire Boston commuter rail system were to be replaced, bus service capable of carrying all former rail riders going to or from Boston would require approximately 240 buses, excluding spares which are 17.6% of required buses. The number would vary depending on the ability of the operator or operators to pool vehicles on two or more routes. The MBTA is required by law to give priority to private carriers in establishing new bus routes, but it is not clear in all cases whether qualified private carriers would be interested in operating rail replacement routes. Many private carriers have relatively small-scale operations and would be unable to service additional vehicles at their existing facilities.

An examination of all proposed replacement routes shows that of 243 required vehicles 68 would most likely be run by the MBTA, 128 would most likely be run by private carriers, and 47 might be run by either the MBTA or by private carriers. Table 3-1 shows the breakdown of these vehicle assignments by route.

3.3 Eastern Route

Routes 7 and 8 - These two routes essentially consist of extra trips on existing North Shore MBTA routes, and as such the MBTA should be the operator. Eight buses are required.

Routes 1, 2, 3, 9 and 10A - Serve points outside of the MBTA district, and could be operated by the MBTA only if subsidies from outside communities were provided. Cape Ann Transportation Authority would probably be the source of funding for service outside the district. At the present time, local service in this area is provided by Action, Inc. Routes 1, 2 and 3 would require five buses if run by a single operator. Unless the routes were profitable, a private carrier would need contracts from both the MBTA and outside sources. Route 4, serving Manchester, was intended to be peak period service, with route 2 providing midday trips. Therefore, these two routes would logically be operated by one carrier. Route 3A could be run independently of other routes and would require three buses. Michaud Bus Lines hold operating rights in Gloucester, Manchester and Beverly, and would be a logical candidate to operate service on these routes.

Bus Routes	Private Carrier	MBTA	Total Number of Buses Required*
Eastern Route	31	8	39
Reading Branch	--	18	18
New Hampshire Division	14-19	14-19	33
Fitchburg	0-11	9-20	18
Framingham	12-15	3-6	18
Needham	0-11	13-24	24
Franklin	13-30	0-17	30
Shore Line	58	3	61
TOTAL	128-175	68-115	243

* These figures do not include the spare buses.

PROBABLE DIVISION OF MBTA AND PRIVATE CARRIER BUSES FOR REPLACEMENT SERVICE

TABLE 3-1

Routes 9, 10 and 10A would be most efficiently operated as a unit, and would need 6 buses. Presently there is no fixed-route bus service in either Ipswich or Hamilton (areas served by these routes). Kinson Bus Lines of Newburyport operates express bus service from Newburyport to Boston by agreement with Boston Commuter Lines. One of these carriers might be interested in providing replacement service on these routes.

Route 6 runs from North Shore Shopping Center to Boston. Even though this route does not directly serve any station, it was found that many riders who drive to Beverly Station would reach the shopping Center in less time. Since Hudson Bus Lines already holds operating rights for this route, they could be the operator of extended service. Six buses would be needed for this route.

Route 5 could be run by the MBTA, Michaud or Hudson, and would require eight buses.

3.4 READING BRANCH

The entire Reading Branch is located within the MBTA district. Presently there are no private carriers operating fixed route service in the communities served. One company, Lynnfield Community, Inc., a subsidiary of Hudson Bus Lines, holds operating rights for local routes in Wakefield, but discontinued its last regular route about two years ago. Therefore the MBTA would be the likely candidate to operate replacement service. A total of 18 vehicles would be needed for this service.

3.5 NEW HAMPSHIRE DIVISION

Routes 1, 2, 3 and 4 would serve Lowell and Billerica, which are outside of the MBTA district. The most likely candidate to provide this service is Trombly Motor Coach, which currently operates Lowell-to-Boston express bus service. Another candidate is Vocell Bus Company, which provides local service between Lowell, Billerica and Woburn.

Route 5 service could operate separately from other routes and would require five buses. There are no private carriers presently providing fixed route service in Wilmington. Although the MBTA operates service from Reading to Wilmington, it has recently been reviewed for discontinuance.

Routes 6, 7, 8, 9 and 10 would be express routes to Woburn and Winchester running to Boston. It is necessary

that the operation of these routes be intercoordinated and also coordinated with MBTA route 701. This makes the MBTA the most logical carrier. Fourteen buses would be needed for this service.

In summary, commuter bus service for the New Hampshire Division would require 14 MBTA buses to meet schedules if Wilmington were served by a private carrier, and a total of 19 if served by the MBTA. The midday extension of existing MBTA Route 134W would require no additional vehicles.

3.6 FITCHBURG ROUTE

All communities served by the Fitchburg Route are within the MBTA district except for Acton, which contracts with the MBTA for service.

Routes 1, 3 and 6 would serve S. Acton Station, and the latter two would serve stations in Concord as well. Service on these routes should be coordinated with Routes 2, 4, and 5. This could best be done if the same carrier operated all siz routes. One candidate would be Englander Coach Lines, which operates express bus service from Greenfield and Fitchburg to Boston. Another possible operator is Maynard Bus Service. This carrier currently operates charter service only, but once provided local service in Maynard. The MBTA does not presently operate any bus service in Concord or Acton. The service on these six routes would require 11 buses.

Routes 7 and 8 would most likely be operated by the MBTA. These routes serve Lincoln and Kendall Green (in Weston), and at present there are no private carriers serving Lincoln or Weston. Six buses would be needed.

The MBTA already provides local service at Roberts, so it would be the most likely operator of Route 9. One bus would be needed for this service.

In summary if the MBTA operated routes 7 and 8 plus the proposed additional service on Route 305, eight buses would be needed. If the MBTA operated all service for the Fitchburg corridor, 20 buses would be needed.

3.7 FRAMINGHAM ROUTE

This network would include six routes and would require 18 buses, three on each route. At present, the Gray Line operates express bus service from Framingham to Boston, and Wellesley Fells Bus Lines operates limited-stop service from Framingham, Natick and Wellesley to

Boston. Although neither carrier has all of the necessary operating rights for proposed replacement service routes, both would be candidates for operation of replacement service at Framingham.

Routes 1 through 5: Wellesley Fells would be a logical operator for these routes serving Natick, Wellesley and Wellesley Hills stations. Wellesley Farms Station is further removed from existing private carrier routes than are the others, but could also be a Wellesley Fells operation.

Route 6 would be the only route operated by MBTA on this line. The assumed routing would require three buses, which would be assigned to Cabot Garage. Another alternative would be expanded service on MBTA routes 305 and 531. This would reduce bus running times from Auburndale and West Newton to South Station by ten minutes compared to a route serving all three Newton Stations, and would result in bus times faster than train times. Aurburndale riders would not be provided with a connection to Back Bay buses at Newton Corner under this option, but West Newton riders could use Route 531 for this purpose.

3.8 NEEDHAM BRANCH

Routes 1 through 5 - The MBTA plans to operate this replacement service. However, there is one carrier Metropolitan Coach Service of Needham, which might be interested in operating replacement service for the Needham station(s?). Fifteen buses would be needed for this service.

Routes 6 through 11 - For these routes serving Roslindale, Bellevue, Highland and West Roxbury Stations, replacement service would consist of increased peak frequency or short-turnbacks on existing MBTA routes in West Roxbury. Nine vehicles would be needed to operate this service.

3.9 FRANKLIN BRANCH

If all bus service for this corridor were run by a single operator, a total of 26 buses would be required. If the service were divided among several operators, more buses would likely be needed.

For purposes of assigning operators, the bus routes should be divided into four groups, as follows.

Routes 1, 1A and 1B - These routes serve Franklin, which is outside the MBTA district. The routes would not serve any towns within the district, so it would be the responsibility of Franklin to arrange for replacement service. The proposed routes are similar to an express bus route from Milford to Boston via I-495 and Route 128 operated by Brush Hill Transportation Co. for Plymouth and Brockton Street Railway Co. Either of these two operators might be interested in extending service to franklin. If this service were operated separately from other service, five buses would be needed to meet the designed schedules.

Route 2 would serve Norfolk, which is in the MBTA district but not currently served by either MBTA or private carrier buses. The route could be run independent of other service and would require two vehicles. One likely operator might be Transit Bus Lines, Inc., of Walpole which formerly served Norfolk.

Routes 3 through 9 would be most efficiently provided by a single carrier. At present, A.B.C., Inc. operates a bus route from Providence to Boston via Walpole, Norwood and Westwood, but with restrictions on service to these towns. These restrictions were originally imposed to prevent competition with rail service, but if rail service were abandoned the restrictions could be removed. This would allow A.B.C., Inc. to operate expanded service either in place of, or in addition to the proposed replacement routes. A major disadvantage of this option, however, is that A.B.C. buses are garaged in Providence.

Transit Bus Lines, Inc., of Walpole formerly operated several local bus routes in the Franklin Branch Corridor, but the Company is now primarily a charter and school bus operator. This company would be a possible operator for replacement routes 3 through 9. Another potential operator would be sansone Motors, Inc. of Norwood. This company once operated several fixed routes in the Norwood area but is now in the charter and school bus business exclusively. If operated by a single carrier, routes 3 through 9 would require 17 buses to meet the assumed schedule.

Routes 10, 10A and 10B serve the portion of Dedham in the vicinity of Endicott Station, which is presently served by local bus routes operated by Hudson Bus Lines, Inc. These routes were run for a few years by the MBTA, but the town requested that the service be transferred to a private carrier in order to reduce operating cost. Given this history, it is probable that the town would also want rail replacement service to be operated by a private

carrier rather than by the MBTA. Hudson Bus Lines would be a likely operator for this service. If these routes were operated separately from any other service, six buses would be required.

In summary, it appears that all replacement service for the Franklin Branch might be provided by private carriers.

3.10 SHORE LINE

Section 2 describes ten basic routes and 15 variations, or a total of 25 routes, to provide commuter bus service on the Boston and Providence Main Line and Stoughton Branch. If operated as a unified service, these routes would require a total of 61 buses. This is the largest number of buses required for replacement service in any one corridor. The large number of buses required is a result of heavy ridership, long trips that prevent equipment recycling, and provision of service to both Back Bay and South Station.

Routes 1, 1A, 1B and 1C would provide replacement service to Attleboro Station. Since Attleboro is outside of the MBTA district, it would be the responsibility of the City or its RTA to arrange for replacement service for rail. A total of eight buses would be needed to operate the three proposed Attleboro replacement routes with the schedules assumed.

Routes 2, 2A and 2B would serve Mansfield exclusively. Routes 4 and 4A would serve both Mansfield and Sharon. Mansfield is outside of the MBTA district, so responsibility for providing rail replacement service would fall on the town or its RTA. In the past, the town of Mansfield has been reluctant to provide subsidies to maintain rail service, so there is a strong possibility that if rail service were discontinued, there would be no replacement service. Sharon is within the MBTA district, but the portions of routes 4 and 4A in Mansfield could be eliminated if there was no subsidy from Mansfield. These would be off-peak routes, so it is unlikely that Mansfield would subsidize them and not subsidize routes 2, 2A and 2B. Because of ridership losses, headways would probably be longer than those assumed, and this would reduce the number of buses needed.

Routes 3, 3A and 3B would serve Sharon exclusively. Routes 4 and 4A would be off-peak variations of Route 3, and would extend to Mansfield if a subsidy from that town or its RTA were provided. At present there is no provate carrier bus service in Sharon, but Canton and Blue Hill Bus Line, a subsidiary of Hudson Bus Lines, operates a local route from Mattapan Station to the

Canton/Sharon boundary. Transit Bus Lines of Walpole formerly operated local bus service between Sharon and Walpole. Both of these carriers would be potential operators for rail replacement at Sharon. To meet the assumed schedules of routes 3, 3A, 3B, 4 and 4A, eleven buses would be needed.

Routes 5, 5A and 5B would serve Canton Junction, and Routes 6 and 6A would serve Canton Center and Canton Junction. At present, Canton and Blue Hill Bus Lines operates local service from Canton to Mattapan Station. This company would be a potential operator for rail replacement service for Canton. A total of 13 buses would be needed to operate the five replacement routes.

Routes 7, 7A and 8 would provide replacement service to the Town of Stoughton. Route 8 would also serve Canton Center and Canton Junction. Since Stoughton is outside the MBTA district, it would be the responsibility of the town or of Brockton Area Transit to arrange for replacement service. At present, Bruch Hill Transportation Co. operates a local bus route from Stoughton to Mattapan Station and BAT provides local bus service between Stoughton and Brockton. Either Brush Hill or the BAT contractors would be possible operators for Stoughton rail replacement service. If Route 8 buses were to pick up passengers at Canton Center and Canton Junction, there would have to be a contract with either the MBTA or the Town of Canton. To meet the assumed schedules of Routes 7, 7A and 8, a total of 9 buses would be needed.

Routes 9, 9A and 9B would provide replacement service at Route 128 Station. Hudson Bus Lines operated buses from Route 128 to downtown Boston in 1977, but these attracted few riders. Rail service from Route 128 is much faster than bus service, but if the rail service were discontinued there would be no mass transit alternative to the bus. A total of five buses would be needed to operate Route 128 replacement buses on the assumed schedules.

Route 10 and 10A would provide replacement service to the Readville, Mount Hope, and Hyde Park Stations. At present Readville and Hyde Park are served by MBTA Route 32 to Forest Hills. The MBTA would be the most likely operator of rail replacement service to the three stations. This service would essentially be a modification of Route 32. A total of three buses would be needed to meet the assumed schedules. These buses would be assinged to Arborway.

In summary, most replacement service for the Boston and Providence Main Line and Stoughton Branch could be operated by private carriers. The MBTA would probably operate replacement service to Readville, Hyde Park and Mount Hope. It is likely that 3 buses would be needed by the MBTA and 58 buses by private carriers.

4.0 PHYSICAL AND COST REQUIREMENTS OF COMMUTER BUS

SUMMARY

As part of the analysis of the commuter bus alternative, this section provides a detailed description of the physical and cost requirements of Commuter Bus Service. Included are: 1) a summary of vehicles needed for this replacement, 2) a description of the bus carage capacity constraints and costs, 3) analysis of Downtown bus terminals with their costs, and finally, 4) the impact of analyzed bus services on traffic and circulation on the access highways and downtown streets.

4.1 VEHICLES

Complete replacement of commuter rail service by bus service would require 286 buses, including 17.6% spares. At the present cost of $80,000 per bus ($73,000 in 1977) these buses would cost $22.9 million.

4.2 GARAGES

4.2.1 Bus Garage Capacity

In order to estimate the costs of vehicle dead-heading, buses for the replacement services were assigned to existing garages, and routes were scheduled accounting for pull-out and pull-in. The garages were selected so as to minimize head-head mileage. This selection of garages was used to simplify calculations, even though complete implementation of commuter bus services as described above would require the expansion of existing garages or the construction of new ones.

As of October 1976, the MBTA active bus fleet consisted of 1,016 vehicles. Of these about 85 percent were required to meet daily schedules, while the balance wer spares. In addition, there were 34 buses out of service in storage. The proposed replacement service for commuter rail would require 222 buses to meet schedules. Allowing for spares, 262 buses would be needed. This represents an increase of 26 percent in the active bus fleet. At present, the MBTA's largest single bus maintenance facility is Cabot Garage, where 205 buses are assigned. Buses for rail replacement service would most likely be divided among two or more new garages.

Table 4-1 shows the assumed distribution of commuter buses to existing garages and the number of buses currently assigned to these garages. The commuter bus figures include spares.

4.2.2 Garage Costs

Due to lack of capacity at existing garages, buses for replacement service would probably have to be maintained at new facilities. A single garage for 261 buses would probably cost between $10 million and $12 million at current price levels.* If separate garages for Northside and Southside service were built, the total cost would be somewhat higher because certain economies of scale would be lost. The number of buses assigned to each garage would be about equal. A 130-bus garage is relatively small by current transit industry standards, but is not unheard of. A cost of $15 million for two garages is probably reasonable.

4.3 DOWNTOWN BUS TERMINALS

In addition to the current bus terminals, other sites were studied and analyzed on both the North and South-sides. On the Northside; Haymarket Square (currently used), Hanover St. site, Hanover Hill St. site and the North Station site were among the possible sites that were analyzed. On the Southside the terminal sites analyzed were South Station (currently in use), Copley Square @ St. James Street (currently in use), Copley Square @ Boylston Street, and Copley Square @ Buckingham St. site. Based on the street condition and the terminal costs for each of these alternatives; Hanover St. site on the Northside and South Station and Copley Square (@ St. James Street) site on the Southside were chosen as the best possible sites for new commuter bus terminals.

Distribution of commuter buses to the existing garages is shown in Table 4-1. Following are detailed descriptions of all possible downtown commuter bus terminals.

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* The MBTA's new Charlestown Garage, which is to serve 240 buses is currently under construction at a cost of $9.9 million, excluding land acquisition.

Garages	Commuter Bus Routes Assigned to Garages	Number of Buses Assigned*	1976 Assignments	Percent Increase in Assignment
Lynn	Eastern	46	91	51%
Fellsway	Reading, N.H.	60	65	92%
Arlington Heights	Fitchburg	24	48	50%
Cabot	Framingham	21	205	10%
Arborway	Needham, Franklin, Shore Line	135	183	74%
TOTAL		286	592	48%

* These figures are the total number of buses assigned including the spares.

DISTRIBUTION OF COMMUTER BUSES TO EXISTING GARAGES

TABLE 4-1

4.3.1 Northside

In the analyzis it was assumed that most bus routes replacing Northside lines would terminate at Haymarket Square. A portion of replacement service for the Reading Branch would run to Oak Grove, and some replacement service for the New Hampshire Division would go to Wellington. Most of Fitchburg buses would terminate at the proposed Alewife Station on the extension of the Re Line, only two of Fitchburg bus routes would terminate in Boston. Most Southside replacement routes would terminate at South Station or Copley Square. Some replacement service for the Needham Line would run to Riverside. Replacement service for stations in Hyde Park on the main line would also run to Forest Hills.

If the entire commuter rail system were replaced with the bus system developed in the analysis, the point of greatest congestion would be Haymarket Square. During the peak hour, 8:00 to 9:00 a.m., 47 buses would be scheduled to arrive at Haymarket. This is an average of one arrival every 77 seconds, but arrivals would not occur uniformly throughout the hour. For example, between 8:25 and 8:35 the assumed schedule would have 11 arrivals, or 1 every 55 seconds. The existing Haymarket Square bus loading area is already operating at capacity during peak hours, and certain MBTA and private carrier routes have to make curbside stops outside the busway.

Currently, 25 MBTA express buses and 23 local buses are scheduled to stop at the Haymarket Busway between 8:00 and 9:00 a.m. The proposed replacement service would increase this volume over 100 percent. Therefore, a new or expanded Haymarket bus terminal would be required to serve Northside rail replacement routes. This terminal would probably need 10 to 15 berths to allow for layover of buses between runs.

Three sites were examined as possible locations for a new Northside bus terminal:

1) Hanover Street Lot

This site, owned by the Boston Redevelopment Authority, is located a short distance to the south of the existing Haymarket bus terminal, bounded by Sudbury, Blackstone, Hanover and Congress Streets. There is a direct entrance to the Orange Line Haymarket Station on the west side of the lot. A quick sketch of the sites indicates that a run-through terminal with 15 to 20 platform spaces could be provided there. A ground floor bus terminal could be compatible with construction

such as a parking garage on the site. The interior layout of a bus terminal and locations of entrances and exits would depend to a large extent on the final design of the depressed Central Artery. A bus terminal set up with access to and from existing streets might not be able to operate with the new street pattern. It is also possible that the new street pattern would force relocation of the present Haymarket terminal, and in that case the Hanover Street lot would be the most likely new site. A two-level above ground terminal would be needed at this site to provide sufficient space for both existing and proposed bus routes.

2) Haverhill Street Site

Haverhill Street formerly ran from Causeway Street to North Washington Street. The location of one of the exit ramps from the Central Artery cut off the connection between Haverhill and North Washington Streets, making the portion of Haverhill Street south of Traverse Street a dead end. This dead end segment is now used as a private parking lot, but is still owned by the City of Boston. This lot is bounded to the east by a retaining wall for the Artery ramp and to the west by the abandoned ramp from the Washington Street subway to the old Charlestown elevated line. The land now occupied by this ramp could be regraded to the level of Haverhill Street. With this expansion, the site could be made into an express bus terminal with about ten berths. More capacity could be obtained by using portions of Haverhill Street north of Traverse Street for bus loading.

With the present highway layout, buses using the Haverhill Street terminal would have to enter Boston via the Charlestown Bridge, and follow Causeway Street to Haverhill Street. The intersection of Causeway and Haverhill Streets is very sharp, and may be infeasible for buses to turn through. Structures on both sides of Haverhill Street would prevent widening of the intersection. At the south end of the terminal, buses would use a new exit to Chardon Street, looping back on Canal Street to Causeway Street.

The Haverhill Street site would be less convenient to rapid transit than the Hanover Street site, but is still within acceptable distance. Passengers getting off buses at Haverhill Street would have to walk between 300 and 600 feet to Haymarket Station, depending on which berth the bus used. This is comparable to the walking distance from commuter rail to rapid transit at

North Station. For most passengers walking directly to their final destinations, Haverhill Street would be less convenient than Hanover Street, but more convenient than North Station.

3) North Station Site

Between the North Station waiting room and the commuter train tracks there is a privately owned 250-car parking lot. The tracks originally extended across this lot to the station, and the MBTA plans eventially to re-extend the tracks. If rail service were discontinued entirely, this lot could be used for a terminal for replacement buses. This site is larger than the Hanover Street lot, but is accessible from one side only, so more internal space would have to be used for roadways. It would probably be possible to provide between 20 and 30 loading berths on the site. A connector from the Central Artery to Leverett Circle runs just north of the parking lot. The proposed depressed Central Artery would also have a Leverett Circle connector in about the same location. If it is feasible to construct ramps from this connector to the parking lot, the site could have better access than either Hanover Street or Haverhill Street. Without these new ramps, buses would either have to approach the lot via Charlestown Bridge, Causeway Street and Nashua Street, or via the Artery, Lowell Street and Nashua Street.

Based on passenger convenience and present accessibility, it appears that the Hanover Street lot is the most likely site for a new Northside commuter bus terminal.

4.3.2 Southside

On the Southside, 50 buses would arrive at South Station during the peak hour, or an average of one every 70 seconds, and 29 buses would arrive in Copley Square, or one every 2 minutes. The heaviest ten minutes at South Station would be 8:10 to 8:20, when 25 buses, or 2.5 per minute, would be scheduled to arrive. Abandonment of commuter rail service to South Station would provide space for expansion of the South Station bus terminal, and this might be sufficient to accommodate the replacement service.

Bus routes serving Copley Square now stop on Boylston Street next to the Boston Public Library, turning right on Dartmouth Street to return to the Massachusetts Turnpike. The optimal loading location for replacement routes from an operations standpoint would be the

Square itself, along Dartmouth Street and St. James Avenue, but it is doubtful that there would be community acceptance of the use of the Square in this manner. The present routing improves time for passengers going to the Purdential Center compared to the proposed route, but is less convenient for those going to Copley Square.

1) South Station

The existing South Station busway is located off Atlantic Avenue on a site formerly occupied by railroad tracks. Excavation was required to bring the site to street level. The busway is designed for run-through operation, and has two platforms, each capable of accommodating 13 to 14 buses. The main user of the busway is Plymouth & Brockton Street Railway Co. The Gray Line, Inc. and Greyhound also route some buses there. Ten berths are used for current P&B operations. When the busway was designed, the MBTA was planning to terminate its Massachusetts Turnpike buses there, but because of objections from riders the terminal was left at Chauncy Street. Because of this, the busway has considerable excess capacity. P&B uses the extra berths to store buses, but this could be done elsewhere.

Commuter bus service would require peak capacity for about 25 buses. It would be necessary to add a third platform to accommodate this traffic. This would require elimination of at least two more railroad tracks, and more excavation. The tracks that would be eliminated are used only for commuter service, which would be replaced by the buses. Expansion of the busway in conjunction with commuter rail abandonment would not interfere with Amtrak operations.

2) Copley Square Area

All commuter trains on the Southside stop at Back Bay as well as South Station. In the analysis it was assumed that replacement service for Back Bay Station would be provided by a terminal in the Copley Square area. Location requirements for this station are complicated by the fact that some buses would approach from the Massachusetts Turnpike and terminate at Copley, some would approach from the Turnpike and continue to South Station, some would approach from South Station and terminate at Copley, and some would approach from South Station and continue to the Turnpike. Therefore, the site must have good access to and from the Turnpike and to and from roads leading to South Station. The sites analyzed are discussed below.

2a) St. James Avenue

In this alternative, buses from the Turnpike terminating at Copley would take the Copley Square exit and follow Huntington Avenue to Dartmouth Street. Turning left on Dartmouth, the buses would drop off passengers opposite the Boston Public Library. They would then loop on Boylston Street, Clarendon Street and St. James Avenue, and layover on St. James Avenue opposite the Copley Plaza Hotel. Buses running through to South Station via Back Bay would leave the Turnpike at Copley Square, follow Huntington Avenue to Dartmouth Street, and drop off passengers at the corner of Stuart and Dartmouth Streets. They would then proceed via Stuart Street toward South Station. Buses originating at South Station and serving Back Bay en route to the Turnpike would stop on St. James Avenue opposite the Copley Plaza, and then follow Huntington Avenue to the Turnpike. Buses serving both South Station and Back Bay and originating and terminating at Copley would approach Copley from South Station via St. James Avenue. They would lay over at St. James Avenue, then loop at Dartmouth, Boylston and Clarendon Streets to Stuart Street, returning to South Station via Stuart.

With the schedule assumed in the analysis, layover capacity for a maximum of eight buses would be needed. In the St. James Avenue alternative, this would require reservation of a lane from Dartmouth Street to a point beside Trinity Church. Except for brief times during the peak hour, the line would be much shorter than the maximum.

The curb lane on the north side of St. James Avenue west of Trinity Place is currently reserved for parking of sightseeing buses. There would be some conflict between rail replacement bus operation and sightseeing bus operation. However, replacement service would be heaviest in peak hours, while sightseeing operations would be most intense during midday. More information on actual use of the St. James Avenue terminal by sightseeing buses is needed in order to determine how serious the conflict would be.

From Trinity Place to Dartmouth Street, St. James Avenue has five lanes. As noted above, the northern curb lane is reserved for sightseeing buses. The southern curb lane, next to the Copley Plaza, is reserved for cabs. From Clarendon Street to Trinity Place there are only three lanes, and parking is not allowed on either side. Therefore there is no room for bus storage in this area. The five-lane section would accommodate about six buses, or two less than the peak capacity needed.

2b) Boylston Street

At present, the MBTA's Turnpike express buses to Back Bay lay over on Boylston Street next to the Boston Public Library. To reach this terminal, the buses take the Prudential exit from the Turnpike and follow Huntington Avenue, Belvedere, Dalton and Boylston Streets. This routing provides excellent access to the Prudential Center, but is circuitous for passengers going to Copley Square or points east. To return to the Turnpike the buses turn right on Dartmouth Street to Huntington Avenue to the Turnpike entrance. Buses through-routed to South Station could either bypass the Boylston Street terminal, as in alternative (a), or they could stop at Boylston Street and then continue via Boylston, Clarendon and Stuart Streets to South Station. Outbound buses from South Station would either have to approach the Boylston Street terminal circuitously via the Prudential Center, or use a different terminal. It is less important that all buses discharge passengers at the same stop than that they all pick up at the same spot. As long as drop-off points are in the same general area, passengers can get to their destinations from wherever they are dropped off. However it is confusing to passengers if buses going to the same destination don't all pick up at the same points. Therefore, buses originating at South Station and also serving BAck Bay would probably have to use the circuitous route and stop at Boylston if the main Back Bay terminal were there. Buses terminating at Boylston but stopping first at South Station would approach the Boylston terminal via the Purdential Center. They would lay over next to the Library, then return to South Station via Bolyston, Clarendon and Stuart Streets.

As noted above, the Boylston Street site is already used by the MBTA's Turnpike express routes to Back Bay. With present schedules, capacity for two buses is needed. In addition to the express buses, the Boylston Street stop is used by Route 55, Copley Square - Jersey and Queensbury Streets, and by Route 68 (East Concord Street to Copley Square). These routes require an additional two loading spaces. Route 39, the temporary replacement route for Arborway streetcar service, also stops on Boylston Street, and may require several spaces when vehicles become bunched. This route will be discontinued once there are sufficient streetcars available to run a full Arborway schedule. Adding replacement buses to the four permanent routes stopping on Boylston Street would result in a line of buses extending at times from Dartmouth Street to a point west of Exeter Street.

At present, the south curb lane on Boylston Street from Dartmouth Street about halfway to Exeter Street is reserved for bus stops at all times, but the two berths closest to Dartmouth Street are for sightseeing buses. This leaves space for only three or four MBTA buses. For the rest of the distance to Exeter Street, parking is banned from 7:00 - 9:30 a.m. This ban probably applies to buses as well as to other traffic. Conversion of this lane to peak bus stops would reduce peak capacity of this section of Boylston Street if the curb lane is in fact used as a running lane. On Boylston Street west of Exeter Street, for a distance of about 300 feet most of the southern curb lane is reserved for cabs.

Because of conditions noted above, it would probably be impossible to provide sufficient capacity for Back Bay rail replacement buses at the Boylston Street site.

2c) <u>Buckingham Street Site</u>

This site, located next to Back Bay Station, would be the most costly and least convenient of the three options. At present there is a 56-car parking lot located on a deck over the railroad tracks east of Back Bay Station. The dimensions of this lot are too small for needs of a run-through bus terminal. A dead-end terminal for eight to ten buses could be provided there. This is undesirable because all buses would have to back out, but nevertheless it may be worth further examination.

If the deck over the railroad were extended from its present limit to Clarendon Street, a run-through terminal for 10 to 12 buses could be provided. In order to provide the maximum number of berths, the terminal would have to be designed for buses to enter at the east end and exit at the west end. Replacement buses serving both Back Bay and South Station and terminating at South Station would by-pass the Buckingham Street terminal eastbound, and would stop instead near the intersection of Stuart and Dartmouth Streets. Westbound buses would follow Kneeland Street to Park Square, then Columbus Avenue, Clarendon Street and Buckingham Street to the terminal. After leaving the terminal the buses would take Buckingham Street, Dartmouth Street and Huntington Avenue to the Turnpike.

Buses serving both South Station and Back Bay and terminating at Back Bay would follow the route described above to the Buckingham terminal. They would then take Buckingham and Dartmouth Streets to Stuart Street, returning to South Station via Stuart.

For buses serving Back Bay only there would be two routing options. The first would be to take the Dartmouth Street exit from the Turnpike and follow Dartmouth Street, Columbus Avenue, Clarendon Street and Buckingham Street to the terminal. The second options would be to use the Copley Square exit ramp from the Turnpike and follow Huntington Avenue, Dartmouth Street, Columbus Avenue, Clarendon Street and Buckingham Street to the terminal. Although this option would be longer than the first, it would allow buses to stop near the intersection of Huntington Avenue and Stuart Street, providing a more convenient drop-off point for most passengers.

Regardless of the approach route, outbound buses originating at Buckingham Street would follow Buckingham Street, Dartmouth Street and Huntington Avenue to the Turnpike.

Buckingham Street is a narrow, two-lane roadway, currently one-way westbound. Besides Back Bay Station and the adjacent parking lot, the only structure on Buckingham Street is a 400-car garage reserved for employees of the New England Merchants National Bank and the John Hancock Mutual Life Insurance Company. There are signs directing traffic through Buckingham Street as an access road from Columbus Avenue to the Massachusetts Turnpike. Because of the garage and Turnpike access provided by Buckingham Street, it would not be feasible to convert it to an exclusive busway. Traffic counts on the street would be needed to determine whether construction of a bus terminal would produce serious traffic congestion.

4.3.3 Terminal Costs

There is a range of terminal possibilities which makes it difficult to estimate bus terminal costs.

The proposed commuter bus service would require about 22 berths at South Station. There is already some excess capacity at this terminal so that one additional roadway and platform would be sufficient. If the new facilities were similar to those already there, the cost would be $150,000 to $200,000. The platform width at this terminal does not provide enough space for shelters, but a roof could be added to the platform at some additional cost.

At Copley Square the most probable plan, use of the northern curb lane on St. James Avenue, would involve no capital expense unless shelters were constructed. The Buckingham Street alternative would involve construction of approximately 12,000 square feet of new deck over railroad tracks east of Back Bay Station. If the

existing deck proves to be unacceptable to busway service, an additional 13,000 square feet of new deck would be needed. The cost of a deck alone would be about $500 per square foot, so a 12,000 square-foot deck would cost about $6 million, and a 13,000 square-foot deck would cost about $6.5 million, or a total of $12.5 million. Platforms and shelters on the deck would probably add at least $200,000 to this cost.

On the Northside, the least expensive terminal would be the Hanover Street lot. If this site were used for a ground level busway only, similar to the South Station busway, the capital cost would be about $300,000, excluding shelters. The cost of simple shelters, installed, ranges from $3,000 to $10,000, depending on dimensions. A terminal on this exposed site would require at least $50,000 worth of shelters bringing the total to $350,000.

At the North Station site, construction cost of a bus terminal alone would be similar to cost at Hanover Street. However, construction of special ramps to the Central Artery would significantly increase the expense. In order to provide acceptable grades, the ramps would have to be at least 800 feet long. This would result in a cost of roughly $20 million for an on-ramp and an off-ramp.

4.4 IMPACT ON TRAFFIC AND CIRCULATION

The commuter bus servides designed as replacements for commuter rail would operate on the existing streets and highways of the Commonwealth. Therefore, this service has a direct effect on traffic flow on these roads. The greatest impact is felt in downtown Boston and on the approach highways to downtown.

4.4.1 Access Highways

I-93, Central Artery

Replacement services for the entire Eastern Route and the New Hampshire Division plus Reading Station on the Reading Branch would result in a peak-hour increase of 45 buses using the Central Artery. The current peak hour inbound traffic volume on this route is 4,600 vehicles, which is below theoretical capacity. However, the narrow merge/weave section on the high bridge over the Charles River is already a severe constraint to traffic flow due to the short length of that section. This problem should be partially remedied by the reconstruction of the "North Terminal" section of the Central Artery. In addition, since most of this bus service would come over the Mystic River Bridge, it would not be a part of the traffic that undergoes that weave.

The additional bus volume from replacement service should not increase congestion significantly on the Artery, the Mystic River Bridge or I-93. In addition, drivers on existing MBTA bus routes operating over the Mystic Bridge have the option of exiting in Charlestown and entering downtown Boston via the Charlestown Bridge when congestion is heavy. Replacement buses for the Eastern Route, totalling 22 in the peak hour, would also have this option. The Charlestown Bridge carries about 1,800 inbound vehicles in the peak hour.

Massachusetts Turnpike and Extension

Bus service for the Fitchburg Route was designed assuming the completion of the Red Line extension. Most of the Fitchburg replacement service would terminate at the Alewife Station. Only buses serving the Kendall Green Station would continue to run to Post Office Square via the Massachusetts Turnpike Extension.

The majority of buses (67) serving the Southside would approach Boston via the Massachusetts Turnpike Extension rather than the Southeast Expressway (4 buses) due to the congestion on the latter route. Since the Turnpike normally operates well below capacity, 67 new peak hour bus trips should cause no problem.

4.4.2 Downtown Streets

Proposed replacement buses operate to the vicinity of Haymarket, South Station and Copley Square. They travel to these destinations primarily over New Chardon, New Congress, New Sudbury and Federal Streets to the Haymarket bus terminal; Kneeland Street and Atlantic Avenue to South Station; and Dartmouth and Boylston Streets to Copley Square. Routings and streets affected depend on the location of the terminal site chosen for each service. There are three possible sites near Haymarket, one at South Station and three at Copley Square.

The most likely site near Haymarket is a vacant lot on Hanover Street, with overflow along New Congress Street. At the present time there is very little peak period congestion on the streets required to access this site. Buses would turn right onto New Chardon from the Central Artery ramp, left onto New Congress, left onto New Sudbury, weave across three lanes of traffic and then turn into the lot. It might be worthwhile to change the street pattern so that the routing into this lot would be simplified. As it presently operates, the left onto New Congress and the weave across New Sudbury are potential sources of congestion. The peak ten minutes would have fifteen buses making this movement.

After Alewife Station on the Red Line opens, most commuter bus service for the Fitchburg Branch would access that station, with only a few trips to Copley Square or downtown. The Alewife Station is being designed to accommodate feeder buses, so there should be little or no trouble caused by Fitchburg Line commuter bus service.

Service to the South Station area that arrives along the Massachusetts Turnpike would cause or encounter no local street congestion, since the Turnpike's ramp is almost at South Station. Buses would only be on Kneeland Street and Atlantic Avenue for a short distance. However, those peak hour buses which would serve both South Station and Copley Square might affect Stuart-Eliot Street, Park Square and St. James Avenue. Efforts must be made to alleviate the impact of these buses. A rebuilt Park Square, which is part of the Park Plaza project, could be designed to alleviate one congestion point, while a traffic signal at Arlington Street would relieve the problems encountered there.

In the Copley Square area, buses could terminate at two on-street sites - St. James Avenue, across from the Copley Plaza Hotel, and on Boylston Street in front of the Public Library. In traveling to the St. James Avenue site, the one potential cause of congestion is the left turn onto Dartmouth Street from the Massachusetts Turnpike exit ramp. This can be relieved by some simple traffic engineering. Another potential problem is the right turn from Boylston Street to Clarendon Street. This would be a problem only if cars parked too close to the intersection on either of the two streets. Only 16 buses will make this movement during the peak hour.

Access to the Boylston Street site would be by way of Huntington Avenue, Belvedere and Dalton Streets. Potential causes of conflict are with auto traffic entering the Purdential Garage whether from Huntington Avenue or from Boylston. However, only 23 buses would follow this path during the peak hour.